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U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ENTOMOLOGY—BULLETIN NO. 88.

L. O. HOWARD, Entomologist and Chief of Bureau.

PREVENTIVE AND REMEDIAL WORK AGAINST MOSQUITOES.

BY

L. O. HOWARD, Ph. D.,
Chief of Bureau.

Issued June 20, 1910.

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BUREAU OF ENTOMOLOGY.

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ROLLA P. CURRIE, *in charge of editorial work.*
MABEL COLCORD, *librarian.*

LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Entomology,
Washington, D. C., March 29, 1910.

Sir: I have the honor to transmit herewith the manuscript of a bulletin on preventive and remedial work against mosquitoes.

It is my hope, with your approval, to follow this with four other bulletins and a circular, all relating to mosquitoes, and to prepare the series in such a way as to bring about a measurably complete consideration of these annoying and dangerous insects for North America.

I respectfully recommend that this manuscript be published as Bulletin No. 88 of this Bureau.

Respectfully,

L. O. Howard,
Entomologist and Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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PREVENTIVE AND REMEDIAL WORK AGAINST MOSQUITOES.

INTRODUCTION.

For many centuries humanity has endured the annoyance of mosquitoes without making any intelligent effort to prevent it except in the use of smudges, preparations applied to the skin, and in removal from localities of abundance. And it is only within comparatively recent years that widespread community work against mosquitoes has been undertaken, this having resulted almost directly from the discoveries concerning the carriage of disease by these insects.

As obvious a procedure as it might seem to be, the abolition of mosquito-breeding places is a comparatively new idea. The treatment of breeding places with oil to destroy the larval forms is, however, by no means recent. As early as 1812 the writer of a work published in London entitled "Omniana or Horæ Otiosiores" suggested that by pouring oil upon water the number of mosquitoes may be diminished. It is stated that in the middle of the nineteenth century kerosene was used in France in this way, while in the French quarter in New Orleans oil was placed in water tanks before the civil war, the idea having possibly come from France to New Orleans or vice versa.

Another early recommendation of the use of oil was given by an anonymous writer in the Magazin Pittoresque,[a] in an article on the "Mosquito and Its Metamorphoses." The phraseology translated into English is as follows:

> When one has recognized that the ponds or ditches existing close to houses are swarming with the larvæ of mosquitoes, one can immediately destroy this dangerous race by spreading on the surface a little oil, which extends in a very thin film and prevents the little insects from coming up to breathe. This proceeding is especially easy to put into practice upon the irrigating tanks in gardens, since it is in such places that the greatest number of mosquitoes develop.

Again, quite recently, Mr. John P. Fort, of Athens, Ga., has communicated to the writer that about the year 1854, while his father, Dr. Thomlinson Fort, was physician to the penitentiary at Milledgeville, Ga., a place of about 2,000 people, the institution had become so infested with mosquitoes as to cause much complaint. Doctor

[a] Vol. 15, pp. 178–182, 1846.

Fort had the matter investigated, and it was found that the mosquitoes originated in the tan vats of a tanyard in the penitentiary and in a large cistern attached to the livery stable in the city. He ordered oil to be put upon the water in the tan vats and the mosquitoes were destroyed.

In 1892 some exact experimentation was undertaken by the writer in Green County, N. Y., which indicated the amount of kerosene necessary for a given water surface, and the duration of efficiency. These experiments also showed that adult mosquitoes are captured by a kerosene film—that is to say, adult females alighting on the surface of the water for the purpose of depositing eggs or for drinking are destroyed by the kerosene before the eggs are laid. The account of these experiments, published in Insect Life,[a] attracted much attention by persons interested and received extended newspaper notices, from which it resulted that practical work on a larger or smaller scale was carried on with success by H. E. Weed, at the Mississippi Agricultural College; by Dr. John B. Smith, on Long Island; by Prof. V. L. Kellogg, on the campus of the Stanford University of California; by Rev. John D. Long, at Oak Island Beach, Long Island Sound; by Mr. W. R. Hopson, near Stratford, Conn.; by Mr. R. M. Reese, in Baltimore; by Mr. W. C. Kerr, on Staten Island; by Mr. M. J. Wightman, at an Atlantic coast resort; and by Dr. St. George Gray, in the British West Indies. The publication of the extensive mosquito article in the bulletin on household insects[b] by the writer and Mr. Marlatt intensified this interest, and was productive of other successful work.

With the discovery of the disease-bearing relation of mosquitoes, first with malaria and next with yellow fever, public interest in their destruction became intensified, and large-scale remedial work was done at many points. Bulletin No. 25,[c] by the writer, devoted considerable space to the subject of remedies, and indicated in the main those remedies which are of use to-day and are to be recommended upon a sound basis of practical experimentation. It is probably unfortunate that the writer in this bulletin laid so much stress upon the use of petroleum as to obscure in a way the much more vital measures of thorough drainage and the complete abolition of breeding places; but the idea that was prominent in his mind at the time the bulletin was written was "Let us stop mosquito breeding at once in an economical way, and then let us take our time in more expensive, more elaborate, and more radical measures." The same criticism can be made and the same partial, though by no means

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[a] Vol. 5, No. 1, pp. 12–14, September, 1892.

[b] Bul. 4, n. s., Div. Ent., U. S. Dept. Agr., 1896.

[c] Bul. 25, n. s., Div. Ent., U. S. Dept. Agr., 1900.

satisfactory, explanation in the case of a book entitled "Mosquitoes,"[a] published in the spring of 1901; but both bulletin and book served a good purpose, and together undoubtedly helped to start, to a great measure, the antimosquito work which has since been carried on in the United States.

Practically beginning with 1901, there has been a rather rapid increase in antimosquito work by individuals and communities, but this work has not progressed with anything like the rapidity demanded by the distressing conditions of many localities and in fact of great areas. Yet it is probably accurate to state that more effective work of this kind has been done in the United States than in any other country. This is probably due to the greater prevalence of mosquitoes in the United States than in any other highly civilized country, but the well-known practical character of the American people is also an element.

During the summer of 1900 Mr. W. J. Matheson carried on some admirable antimosquito work at his large place at Lloyds Neck, Long Island, N. Y. This work was thoroughly done and was most successful, no mosquitoes breeding where they had previously swarmed to such an extent as to render the localities uninhabitable. In the autumn of 1900 there was a migration of salt-marsh mosquitoes to Lloyds Neck from salt marshes bordering on Center Island. Mr. Matheson induced the practical residents of Center Island to take up extensive work during the summer of 1901, and this work was carried through in a very perfect manner by Mr. H. C. Weeks, engineer in charge, and was described in the Century Magazine for July, 1902. In the summer of 1901 was also begun by far the largest piece of work as yet undertaken. It originated on the "Northern Shore" of Long Island, in the regions between Hempstead Harbor and Cold Spring Harbor, and was carried on under the auspices of the North Shore Improvement Association, a group of wealthy and prominent residents of this part of the island. The work during the summer of 1901 included an almost microscopic survey of the region and the preparation of a map showing the breeding places of the several kinds of mosquitoes. It included also the preparation of reports by entomological experts, a report by Professor Shaler, of Harvard University, on marsh areas and related subjects; an account of the work done on Center Island during 1901; and engineering reports, including recommendations for treatment, by Mr. H. C. Weeks. A volume was published in the spring of 1902 entitled "Reports on Mosquitoes, with Map,"[b] which forms a very sound basis for thorough ocean-shore community work for some time to come. Following the survey of the work by the North Shore Improvement Association in 1901 there were carried on by private individuals and by the association in 1902

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[a] "Mosquitoes." By L. O. Howard. 1901. [b] New York, 1902.

certain remedial and preventive operations. One of the most interesting of this series was performed on the estate of Mr. W. D. Guthrie. By means of a dike and a sluice gate a large marsh area was drained, and the breeding of the salt-marsh mosquitoes was stopped. A stretch of 75 acres of land was reclaimed and the soil was disintegrated and properly treated, with the result that cabbages, turnips, and celery were grown at the close of the summer of 1902.

The year of 1902 was also marked by the first effort to secure anti-mosquito legislation from one of the United States. The state entomologist of New Jersey, Dr. John B. Smith, backed by an intelligent public sentiment, tried to secure the passage of a bill by the state legislature during the winter of 1901–2, appropriating $10,000 for the purpose of investigating the possibilities of the wholesale destruction of the salt-marsh mosquito and other kinds of mosquitoes. The bill passed one branch of the legislature, but failed in the other branch. The governor of the State, however, was able in other ways to provide Doctor Smith with a limited sum to carry on researches. In this work he discovered a number of most interesting and vitally important facts concerning breeding habits of the salt-marsh mosquitoes, indicating that the breeding places of these species are more or less circumscribed, and that the matter of control is by no means as expensive as it appears at first sight, and it was these discoveries that eventually led to the passage of the law which will be mentioned later.

Admirable community work was taken up during 1901–2 by certain New Jersey towns, notably South Orange, Elizabeth, Montclair, Monmouth Beach, and Summit. Independent work was begun in Greater New York under Doctor Lederle, and the mapping of mosquito breeding places within city limits was begun. Independently, the health officers of Brooklyn, Jamaica, and Bronx Borough began efficient work, while the summer resorts of Arverne and Woodmere reduced the mosquito supply by intelligent operations. At Willets Point intelligent and efficient work was carried out on a small scale. In Massachusetts interesting and important work was done at Brookline and at Worcester. In Brookline the board of health first considered the work in August, 1901, and in September all the breeding places of the malaria mosquito and of the other mosquitoes were treated. In 1902 all pools, ponds, ditches, and other breeding places, including catch-basins, were located on the town map. The approximate areas were determined and the number of catch-basins ascertained. Breeding places of Culex and Anopheles, respectively, were determined, and also the places where both the species were breeding—this being done in order to ascertain the proper intervals for treatment; that is, whether every two weeks or every three weeks. Public dumps and other places where accidental receptacles of water

might be found were also located on the maps. Light fuel oil was used on all breeding places. The public dumps were found to be very important in the work, since many accidental receptacles, like bottles, cans, wooden and tin boxes, and the like, were to be found. Where these were breakable, they were simply broken; when not, they were carried and dumped into pools to assist in filling these.

This Brookline work was so thorough that the community was greatly relieved from the mosquito pest, although in the autumn some low meadows near the town, where drainage work had been postponed, were found to be breeding mosquitoes in great numbers.

At Worcester the work was of the most interesting kind. Dr. William McKibben and Dr. C. F. Hodge started the crusade. Breeding places were mapped and photographed and public lectures were given. The school children of the several grades were interested and were organized into searching parties. Many breeding places were filled, and others were treated with kerosene. A strong point was made in Worcester, by those engaged in the crusade, by the prevalence of malaria in many places in the city. The relation between the mosquito-breeding places and the houses where there were malaria patients was effectively pointed out, and a map was prepared showing the exact distribution of malaria in the city, and photographs were made showing the character of the breeding places of the malaria mosquito. It is probable that these Worcester efforts to interest the school children were the first made in this direction, although the idea was carried out to a much greater extent later in San Antonio, Tex., under Doctor Lankford, as will be pointed out on subsequent pages. Other work during the summer was carried on at Pine Orchard and Ansonia, Conn., at Old Orchard Beach, in Maine, and on the campus of the Michigan Agricultural College, in Michigan. Strong efforts were made during the summer to start work at Baltimore, but for a time the city council refused to make appropriations. At Atlanta, Ga., the sanitary department used a large amount of kerosene in the stagnant pools and swampy places around the city, and warned the citizens to watch their rain barrels and keep their gutters open. A great many pools of water were drained, and in the negro quarters of the city the sanitary inspectors were constantly on the lookout for standing water in buckets and other chance receptacles. The matter was taken up with the county commissioners, and the area of preventive measures was extended toward the close of the season. In Savannah some work was done, and the number of mosquitoes reduced very considerably. Oil was used diligently by the sewer-cleaning forces, and was placed in the catch-basins. So great was the relief that many people in Savannah for the first time used no mosquito bars. At Talladega, Ala., under the direction of Dr. B. B. Simms, antimosquito work was commenced early in the season,

and was carried out systematically and thoroughly. No place that could possibly prove a breeding place was overlooked. The application of kerosene was repeated several times during the year. St. Louis took up the work early in July, and the municipal assembly made an appropriation for supplies. The health department, however, was hampered for lack of men, and little work was done.

Such were the early steps in the mosquito crusade in this country. Many other communities have taken up the work since 1902. Some, through inefficient work, have allowed their efforts to lapse, and have become more or less indifferent. Others have gone ahead and have spent considerable sums of money in their mosquito fight.

In the early days of mosquito warfare there was great indifference combined with incredulity as to the danger from mosquitoes, even among the medical profession, and particularly in the South. This indifference and incredulity, however, have now, for the most part, passed away. Boards of health very generally appreciate the desirability of antimosquito work, and as rapidly as town councils can be induced to appropriate the necessary funds the work is going ahead.

Excellent antimosquito work has been carried on during the past few years in Honolulu, backed by rather modest funds, under the direction of the then entomologist of the Hawaiian Agricultural Experiment Station, Dr. D. L. Van Dine. In Porto Rico some work is being done, as well as in the Philippines, under the United States Government. In Cuba and in Panama the work has been of a standard character and the operations at these points will be more fully mentioned in subsequent paragraphs.

In other parts of the world many striking examples of the value of antimosquito work have been shown comparatively recently, and several of these will be detailed later.

PROTECTION FROM BITES.

PROTECTIVE LIQUIDS.

A number of different substances have been in use to rub upon the skin or to put near the bed as a protection from mosquitoes. Spirits of camphor rubbed upon the face and hands, or a few drops on the pillow at night, will keep away mosquitoes for a time, and this is also a well-known property of oil of pennyroyal. Oil of peppermint, lemon juice, and vinegar have all been recommended for use as protectors against mosquitoes, while oil of tar has been used in bad mosquito localities. A mixture recommended by Mr. E. H. Gane, of New York, is the following:

Castor oil	ounce	1
Alcohol	do	1
Oil of lavender	do	1

The oil of citronella has come into very general use in the United States in the past few years. The odor is objectionable to some people, but not to many, and it is efficient in keeping away mosquitoes for several hours. A mixture recommended by Mr. C. A. Nash, of New York, composed of 1 ounce oil of citronella, 1 ounce spirits of camphor, and one-half ounce oil of cedar, has been the most efficacious mixture tried by the writer. Ordinarily a few drops on a bath towel hung over the head of the bed will keep *Culex pipiens* away for a whole night. Where mosquitoes are very persistent, however, a few drops rubbed on the face and hands will suffice. This mixture, in the experience of the writer, has been effective against all mosquitoes except *Aëdes* (*Stegomyia*) *calopus*, the yellow-fever mosquito. This mosquito begins to trouble the sleeper at daybreak, and by that time the potency of the mixture has largely passed, and one is apt to be in his soundest sleep. If, however, one could arrange to be awakened just before daybreak and apply the mixture, returning for the last nap, it is probable that it would be efficacious.

Fishermen and hunters in the north woods will find that a good mixture against mosquitoes and black flies can be made as follows: Take 2½ pounds of mutton tallow and strain it. While still hot add one-half pound black tar (Canadian tar), stir thoroughly, and pour into the receptacle in which it is to be contained. When nearly cool stir in 3 ounces of oil of citronella and 1½ ounces of pennyroyal.

Oscar Samostz, of Austin, Tex., recommends the following formula:

Oil of citronella	ounce	1
Liquid vaseline	ounces	4

Apply freely to exposed parts.

Doctor Durham, of the English Yellow Fever Commission, Rio de Janeiro, told the writer that he and the late Doctor Myers found that a 5 per cent solution of sulphate of potash prevented mosquitoes from biting, and that they were obliged to use this mixture while at work in their laboratory in Brazil to prevent themselves from being badly bitten.

An anonymous correspondent of American Medicine, who signs himself F. A. H., says:

> I would advise the use of the oil of cassia, for the odor is not offensive to human beings and it is an irritant poison to all kinds of insects. Besides, its power remains for a long time after it has dried.

Pure kerosene has been used for this same purpose. An excellent example of its practical use came to the writer in a letter from Dr. W. H. Dade, an army surgeon, writing from the Philippine Islands under date of November 15, 1901.

He stated that during November, 1900, while traveling up the Cagayan River on the steamer *Raleigh*, they were bothered greatly by mosquitoes both during the day and night, Culex and Anopheles

both being present and breeding in fire buckets along the sides of the vessel. The buckets were teeming with larvæ. They did not seem to have thought of putting kerosene on the buckets in order to stop the breeding, but at the suggestion of Doctor Dade a rag was saturated with kerosene, the face, hands, and feet were smeared with it, and the rag was put where it could be conveniently reached. When aroused from sleep by mosquitoes another application was made. "Those who had not used these means before seemed perfectly surprised at the splendid immunity gained. The odor and the greasy feeling imparted were the only drawbacks to its use." Doctor Dade continued to experiment with this remedy after his return from an unsuccessful attempt to capture General Aguinaldo, and found that the addition of 1 part oil of bergamot to 16 of kerosene imparted an odor scarcely objectionable, and at the same time added sufficient body to the kerosene to prevent evaporation in less than six to eight hours. After that, when the soldiers had to leave the post, and after it became impracticable to carry cans with them in the field for a long or protracted march, this mixture was used, with the result that the list of malarial patients was noticeably shortened. The oil of bergamot was hard to obtain and is too expensive to be used wholesale, but the soldiers rarely objected to the odor of kerosene and the bergamot was not continued.

In moist tropical regions where one perspires profusely, the oily mixtures considered under this heading applied to the skin are transient in their effects. Under these circumstances they should be applied rather liberally to the clothing, particularly about the neck and wrists.

SCREENS AND CANOPIES.

Such obvious measures as the screening of houses, the use of netting for beds, and the wearing of veils and gloves after nightfall in badly infested regions, need no consideration in detail. But even in such an apparently simple matter as house screening certain points must be taken into consideration. It may be incidentally stated that with proper treatment of breeding places screening is unnecessary. The expense to which the people of the United States go for screens against mosquitoes and flies is enormous, and has been estimated at $10,000,000 annually. If this expense were at all necessary it should surely be thoroughly done.

In screening a house, as Dr. John B. Smith has pointed out in his Bulletin No. 216 of the New Jersey Agricultural Experiment Station, the attempts frequently fall far short of protection:

> Adjustable, folding, or sliding screens are never tight, and when the insects really want to get indoors they work their way patiently between the two parts of the screen or between its frames and the window. But even a well-fitted screen either sets tightly into the frame or, running like a sash, may offer leaks when a window is only partly

opened. * * * There is abundant opportunity for the insect to get in between the net and lower cross bar; in fact, there is no real protection at all. Where the netting is fixed to the outside of its frame, so that there is no space between it and the lower part of the sash, the insects nevertheless find their way in between the window sashes. * * * It has been already said that the mosquitoes will, in certain seasons, attempt to make their way through the screens, and they have less trouble with wire netting than with any other because the meshes are even in size and the strands smooth. Some of the fabrics used for nettings, especially of the cheaper grades, have the threads so fuzzy that it is simply impossible for the mosquitoes to make their way through, and they rarely even try it except where there is a tear, or where the threads have been spread apart leaving an unusually large opening. Where an onslaught is made on wire netting it can be checked by painting lightly with kerosene or oil of citronella. I have tried both and found them successful.

In addition to these mechanical difficulties it often happens that the cellar and attic windows of houses are not screened. This is a great mistake, since mosquitoes will enter these windows and pass the winter in both cellars and attics.

With regard to bed canopies there is reason for the greatest care. There should be ample material to admit of a perfect folding of the canopy under the mattress, and the greatest care should be taken to keep the fabric well mended. It often happens in mosquito regions that little care is taken of the bed nettings in the poorer hotels, and it is necessary for perfect protection that a traveler in the Southern States should carry with him a pocket housewife and should carefully examine his bed netting every night, prepared to mend all tears and expanded meshes.

Veils and nettings for camping in the Tropics are absolute necessaries. Light frames are made to fit helmetlike over the head and are covered with mosquito netting. Similar frames readily folded into a compact form are made to form a bed covering at night, and every camping outfit for work in tropical or malarial regions should possess such framework and plenty of mosquito netting as an essential part of the outfit.

An illustrated advertisement in Ross's admirable Mosquito Brigades shows a folding-hood mosquito net especially for the use of travelers when taking rest. This is 6½ feet long, 4 feet wide, and 2 feet high. It is a frame arrangement which can be opened by the traveler so as to envelop himself when he is lying down. The frame is easily carried in the hand, being only 40 inches long by 4 inches in diameter when folded. There is also given an illustration of a small, compact mosquito house for use by travelers while writing, reading, or taking their meals. It is large enough to contain two persons seated, and is constructed with a frame which is easily portable. The frames are manufactured by a firm of surgical-instrument makers in Liverpool. No doubt other apparatus of the same kind is manufactured and to be purchased at large outfitting establishments, such as the army and navy stores in London.

Some attention has been paid to the subject of the size of the mesh of screens with especial reference to the yellow-fever mosquito. Working party No. 2 of the Public Health and Marine-Hospital Service, at Veracruz, conducted a few experiments to determine the question of the size of the mesh. Their experiments were conducted by placing screens with a varying number of meshes to the inch over breeding jars and putting bananas, sirup, and other food on the other side so as to tempt the hungry mosquitoes to pass through. The fruit and other food was placed in a jar which was inverted over the mosquito-breeding jar, and a piece of gauze or netting was inserted between the two jars so that the mosquitoes would have to pass through the meshes in order to appear in the upper jar. As a result it was found that both males and females passed through a netting containing 16 strands or 15 meshes to the inch, but could not pass 20 strands or 19 meshes to the inch. It therefore became evident to these observers that the large-meshed mosquito bars ordinarily used in Veracruz would not offer proper protection and that window screening must also be of a finer wire than is sometimes employed.

Goeldi refers to this screen question, both in regard to the yellow-fever mosquito and to the common rain-water-barrel mosquito, in connection with some very interesting observations about the range of variation in the size of the individuals of the same species, a fact which is frequently noticed with other insects but to which special attention has not been called elsewhere with mosquitoes.

Frequently I have observed, both in *Stegomyia fasciata* and in *Culex fatigans*, alongside of individuals of normal stature individuals very much smaller—veritable dwarfs. This observation may be made on specimens captured in freedom as well as on those in captivity, in this last case the phenomenon repeating itself rather frequently. There are sometimes born individuals, both males and females, so small that they easily pass through the mesh of wire gauze much closer than the mesh of "Grassi's gauze" which to-day is produced on a large scale in Italy with a view to the prophylaxis against the Anopheles and malaria (Grassi, himself, recommends a gauze that shall not have less than nine meshes in 1½ centimeters of distance, which corresponds to little linear squares 1.7 mm. to the side). The government of the State of Para imported for my experiments from Italy under this name a gauze which had but six threads to 1½ centimeters of linear extension, corresponding to squares of 2½ mm. along one side. I refer particularly to this last brand, which I consider sufficient as a rule for application to hospitals to impede the invasion of mosquitoes from the outside, but which I found, nevertheless, insufficient for the walls of my cages destined for experiments on mosquitoes like *Stegomyia fasciata* and *Culex fatigans* in captivity.

In general, the phenomena of *macrosomia* and *microsomia* in plants and animals are related directly with greater or less abundant nutrition, and I do not believe that the quoted *dwarf race* of Stegomyia and Culex is to be explained in any other way than by a sparse alimentation and a delayed development in the larval stage. On this point I have at hand experiments in proof: Larvæ reared in clear water—that is to say, relatively poor in assimilable substances—gave me imagos of small stature. Furthermore, it is yet to be shown that I am deceived in my opinion that the

frequency of dwarf individuals captured in freedom is not notably greater at certain periods, assuming almost the character of a rule. Thus this year [1905], in the last weeks of October and November, before we entered fully upon the rainy season, I got the impression that the females of dwarf dimensions were particularly numerous. I doubt that this is the work of a mere accident; it is very possible that the frequency of dwarf individuals, normally possible during the whole year, may be periodic and represent a case, somewhat diminished, of what is called in entomology "*dimorphism of seasons.*" Theoretically there can be no serious obstacle in accepting the argument that in the height of the dry season, with the growing lack of water, the conditions of life for the larvæ become more difficult, thus favoring the generation of mosquitoes below the normal dimensions. Impoverished water and reduced food may really, as we have seen above, oblige the larva to take two or three times the period normally necessary for its development and to acquire the necessary growth for its metamorphosis. I have the feeling that hibernation, in the sense in which this word is accepted in zoologic literature, may well for the tropical and equatorial Culicidæ find its expression in two ways: (1) Delayed development of the larvæ; (2) dwarfed stature of the imagos.

[*Note by translator.*—Doctor Goeldi enters into long explanation as to hibernation, evidently for the benefit of equatorial readers who might accuse him of the mal-use of technical terms. He refers to the phenomenon of "seasonal lethargy" and endeavors to trace a connection between the circumstances favoring the development of the perfect insects in parallelism with the "periodicity of yellow fever." His final paragraph is as follows:]

It would be a mistake to believe that these dwarf individuals of Stegomyia are less aggressive and sanguinary than those of normal stature. They behave in a precisely similar manner; their bites are not less painful, as I have had frequent occasion to prove.

A study of the question of mosquito bars or canopies, both for indoors and out-of-doors, has been made by Dr. F. Arnold, the district medical officer of health, northern Transvaal, and he has published an interesting article on the subject in the Transvaal Agricultural Journal for October, 1907, pages 13–15. He illustrates the mesh of different nettings purchased in Pretoria, labeling a netting with a mesh 1 mm. in width as good, one of 2 mm. as doubtful, and one of 3 mm. as bad. These nettings were tested by stretching them over the mouths of three large pill boxes, and in each pill box was put a known number of live, uninjured mosquitoes. The boxes were placed on a chair alongside his bed, where they remained all night, with the idea that by placing the mosquitoes near a sleeper they would be anxious to get at him, and the natural conditions existing in a bedroom would be imitated; that is, there would be a mosquito and a sleeper separated by a net. The conclusions were those above indicated. Doctor Arnold continues his directions in the following words:

In this country the bell-shaped bedroom mosquito net is almost always used; box-shaped nets are rarely seen. In Eastern countries the box-shaped net is generally used fixed on to a large four-posted bed; such an arrangement has the great advantage that the net can be drawn tight and there is within it so large a space for the sleeper that his limbs, if uncovered, are not likely to come in contact with the net.

Frequently the bell net has too small a ring at the top and the netting is not sewn on to the calico which closes the ring, but is gathered up above it by a running thread; such an arrangement causes folds to be formed in the net above the ring, and through the grooves of these folds mosquitoes enter freely. Again, the net is often allowed to hang loose on the bed or it is drawn over the whole bedstead on to the ground. When hanging loose it affords very little protection, for it will, during the night, certainly come in contact with the face, arms, etc., which will be bitten through the net. If placed right over the bedstead, then its lower margin must be heavily weighted with a long and continuous sand bag, and every care must be taken to drive away mosquitoes which may be sleeping on the dark underside of the mattress; in outlying districts white ants would, in one night, make short work of net and sand bag if lying on a mud floor. How, then, should a net be made and arranged?

Proceed as follows: Obtain a ring of wood or iron, in diameter two and a half to three feet; close it with a piece of stout calico; on this calico, around the circumference of the ring, sew the mosquito net very carefully, using netting of the mesh shown as No. 1. Suspend the net to the ceiling in the usual way. Next arrange the bedding as is done on board ship; that is to say, take the upper sheet, blanket, and counterpane and fold the margins inwards at the sides and at the foot; all of the bedding which will cover the sleeper will then lie on the top of the under sheet. Now tuck the mosquito net under the mattress all around, drawing it tight. On going to bed draw out the net at one side, creep in under it, and carefully tuck it back under the mattress. The sleeper is now in a cage; it does not matter how much he kicks about the net will remain true, and, provided that a fair-sized bed is used, there is not much risk of an unclothed part of the body touching the net. For use on the veldt many kinds of stretchers, etc., have been devised. The writer has used a folding stretcher which carries four thin upright rods. Through eyes in the upper ends of these rods runs a cord, and over the whole structure is placed a box-shaped net. The net sold with the stretcher has its lower margin weighted; it is intended that this lower margin should lie on the ground. But this is a theoretical arrangement. First, one rarely gets a flat piece of ground free of grass and stones whereon to place the stretcher; secondly, a sudden gust of wind causes the hanging net to "ride-up" on the feet of the stretchers; and lastly, a stone or grass lifts up the lower margin of the net.

The net, etc., should be arranged as follows: Take a large, long blanket, 7 feet by 5 feet, fold it lengthwise, and lay it on the stretcher to serve as a mattress. Arrange the blankets which will cover you just as the top bedding is arranged for an indoor bed. Tuck in the net carefully all around under the blanket mattress, taking special care to cross the folds of the net around the upright rods. Crawl in under the net and close it in the usual way. The stretcher used by the writer, when opened for use, measures 6½ by 2½ feet, and stands 15 inches above the ground. The whole outfit (stretcher, rods, and net) weighs 26 pounds and can be packed into a canvas sack measuring 3 feet by 13 inches.

SCREENING BREEDING PLACES.

What we have said in regard to the size and mesh to be used in window screens and canopies applies equally well to screens over possible breeding places to prevent the breeding of mosquitoes or the issuing of mosquitoes which have bred therein. In cities in the Gulf States, where the rain-water supply is conserved in large tanks, screening is necessary and is now enforced, Galveston and New Orleans perhaps being the first to make this an important health measure. But rain-water barrels everywhere must also be screened

in the same way, except where fish are used to kill the early stages of mosquitoes. In out-of-the-way places, however, where it is difficult to get good screens or where the expense of screening is seriously to be considered, a cheap cover may be made for well-mouths or water barrels, such as described by Dutton in his Report of the Malaria Expedition to the Gambia, and which he states was devised by Doctor Forde.

This cover consists of a large iron hoop obtained from discarded barrels, to which is fastened all around a piece of stout calico or sacking free from holes in such a manner that a good deal of sag is left in the material. After water is obtained from the well the hoop is thrown over the mouth, and the calico catching on the rim of the well completely closes the entrance and is kept taut by the weight of the iron hoop. This cover is so simple, and, however carelessly applied, must so effectually close the entrance of the tub against mosquitoes that I think it is well worthy of extensive use in the town. Dr. Forde has lately informed me that these covers are now being made in Bathurst, and are sold to the natives for the sum of four pence.[a]

ABOLITION OF BREEDING PLACES.

In considering this general question just as in considering so many questions relating to mosquitoes, a complication arises from the enormous mass of facts concerning the life histories of the different species of mosquitoes; facts discovered, for the most part, in the past three or four years. At the time of the publication of Bulletin 25, new series, of this Bureau, the specific habits of but a few mosquitoes were known and the generalizations drawn from the knowledge of these few species were altogether too broad and must now be greatly modified. There is much diversity in the breeding places of different species. Those of the two commonest household mosquitoes, namely, *Culex pipiens* in the North and *C. quinquefasciatus* and *Aedes* (*Stegomyia*) *calopus* in the South, correspond well to generalizations formerly named, breeding as these species do in every chance receptacle of water about residences, and their destruction means the abolition of all such receptacles. Where the rain-water barrel or the rain-water tank are necessary they should be screened. In New Orleans and other southern cities the boards of health are now enforcing such screening. This should be done with extreme care, a fine mesh wire being used and the fitting being made very perfect.

About a given house the waste places in the immediate vicinity should be carefully searched for tin cans, bottles, and wooden or tin boxes in which water can accumulate, and all such receptacles should be destroyed or carted away. The roof gutters of the building should be carefully examined to make sure that they are not clogged so as to allow water to accumulate. The chicken pans in the poultry yard, the water troughs for domestic animals, the water cup of the grindstone, are all places in which mosquitoes will breed and in them

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[a] 8 cents.

water should not be allowed to stand for more than a day or so at a time. In the South the water accumulating under water tanks should be treated or drained away. The urns in the cemeteries at New Orleans have been found to breed mosquitoes abundantly. The holy water fonts in Roman Catholic churches, especially in the South, have commonly been found to breed mosquitoes; in some places sponges have been substituted for standing water, and other churches have adopted a closed font, which allows the holy water to issue through a small spigot. In still other churches salt has been put in the water to prevent the breeding of mosquitoes. In slightly marshy ground a favorite breeding place is in the footprints of cattle and horses. In one country village, which contained many small vegetable gardens in a clay soil, during the rainy season mosquitoes were found breeding abundantly in the water accumulating in the furrows in the gardens.

Even in the house mosquitoes breed in many places where they may be overlooked. Where the water in flower vases is not frequently changed mosquitoes will breed. They will breed in water pitchers in unused guest rooms. They will breed in the tanks in water-closets when these are not frequently in use. They will brėed in pipes and under stationary washstands where these are not frequently in use, and they will issue from the sewer traps in back yards in city houses during dry spells in the summer time when sewers have not recently been flushed by heavy rains. In warehouses and on docks they breed abundantly in the fire buckets and water barrels.

In country houses in the South where ants are troublesome and where it is the custom to insulate the legs of the tables with small cups of water, mosquitoes will breed in these cups unless a small quantity of kerosene is poured in. Where broken bottles are placed upon a stone wall to form a cheval-de-frise, water accumulates in the bottle fragments after rains and mosquitoes will breed there. Old disused wells in gardens are frequent sources of mosquito supply, even where apparently carefully covered, and here the nuisance is easily abated by the occasional application of kerosene. The same thing may be said of cesspools. Cesspools are frequently covered with stone and cement, but the slightest break in the cement, the slightest crack, will allow the entrance of these minute insects and unlimited breeding often goes on in these pools without a suspicion of the cause of the abundance of mosquitoes in the neighborhood. The writer remembers, for example, on one occasion walking through a New Jersey garden and noticing a covered cesspool with a slight crack in the cement. He remarked upon the danger to the proprietor of the estate, who replied that mosquitoes could not possibly gain entrance to the water. Later in the evening, about dusk, the

same spot was passed again and a cloud of mosquitoes was seen issuing from the crack so abundantly that at a little distance it seemed like a stream of smoke. A little kerosene put a stop to this.

Fountains and ornamental ponds are frequent breeding places, and here the introduction of fish, as indicated in another place, is usually all-sufficient. It frequently happens, however, that the grass is allowed to grow down into the edges of ornamental ponds and mosquito larvæ find refuge among the vegetation and so escape the fish. Broad-leaved water plants are also often grown in such ponds, and where these broad leaves lie flat upon the surface of the water, as they frequently do, one portion of a given leaf may be submerged so that mosquito larvæ may breed freely in the water over the submerged portion of the leaf, protected from fish by the leaf itself, the fish rising from below. It is necessary, therefore, to keep the edges of such ornamental ponds free from vegetation and to choose aquatic plants whose growth will not permit of mosquito-larvæ protection. In many small country towns, even where there is a water supply, tanks are to be found under the roofs to supply bathrooms. Such tanks should be screened, since mosquitoes gain entrance to the tank-room either through dormer windows or by flying up through the house from below in search of ovipositing places. About a large old house there are so many of these chance-breeding places that only the most careful and long-continued search will find them all. Frequent change of water or the use of kerosene will render them all harmless.

In community work in cities all of the points mentioned must be borne in mind, and in the portions of the community where the residences are for the most part detached villas, in the absence of swampy suburbs the householders are in the main responsible for their own mosquitoes. There are, however, breeding places for which the municipality may be said to be responsible and these entirely aside from public fountains, reservoirs, or marshes. It seems unlikely that in any general sewerage system mosquitoes may breed in the sewers proper. That they do breed in the catch-basins is well known. The purpose of the catch-basin is to catch and retain by sedimentation sand and refuse which would otherwise enter the sewer and deposit in it. It is intended to be watertight and to hold a considerable body of water which stands in it up to the level of the outlet pipe. Such catch-basins are very commonly used in back yards and at the crossings of streets. The water is removed only by rain or when street or yard surfaces are washed. In dry seasons the period of stagnation may last several weeks, certainly long enough for mosquito breeding. As a matter of fact, mosquitoes in midsummer do breed in such basin traps or catch-basins by millions. In the work against mosquitoes in Brookline, Mass., in 1901 and 1902,

previously referred to, *Culex pipiens* was found breeding abundantly in them, and more than 1,000 such basins were regularly treated with petroleum. It is a matter of common observation in the city of Washington that during the usually dry period of late July, August, and September mosquitoes are rather numerous in the northwest quarter of the city where there are no possible breeding places other than these catch-basins, and it is urged that under such circumstances residents make an effort to have such basins frequently treated with kerosene.

The suggestion has been made that in cities it may, under certain circumstances, be possible for mosquitoes to breed in water accumulating in the troughs of underground-conduit electric railways, but so far as known to the writer no exact affirmative observations have been made. That there is abundant opportunity for water to accumulate in these troughs and that it does so accumulate there can be no doubt. It is true that such water will immediately become very dirty, since dirt of all kinds falls into the slot, and it would also be more or less oily. There remains a chance that mosquitoes may breed in this manner, although Gen. George H. Harries, vice-president of the Washington Railway and Electric Company, of the city of Washington, informs the writer that in his opinion this chance is very slight.

DETERRENT TREES AND PLANTS.

There are many references in descriptive literature to certain trees and plants in the neighborhood of which mosquitoes are never found. Notable among these are the eucalyptus trees and the castor-oil plant. Of recent years there have been many newspaper notes about other plants and in southern States the chinaberry tree is said to be distasteful.

EUCALYPTUS.

The statement has often been made that the planting of eucalyptus trees in malarial regions will drive away malaria. This idea had become rather firmly grounded before the discovery of the carriage of malaria by mosquitoes. It has been said, for example, that the planting of eucalyptus trees in the Roman Campagna was followed by a notable improvement in the malarial conditions. Eucalyptus oil has been used to keep mosquitoes from biting. Mr. Alvah A. Eaton, of California, wrote to the Bureau of Entomology, in 1893, that in his opinion where the blue gum grows no other remedy against mosquitoes need be sought for. He further stated that, no matter how plentiful mosquitoes may be, a few twigs or leaves laid on the pillow at night will secure immunity. Another correspondent of the Bureau, Mr. W. A. Saunders, wrote from California that he had planted eucalyptus trees about his house nineteen years previously and that they had

reached a height of 140 feet. According to his statement, an irrigating ditch ran through the grove, but there was never a single mosquito larva in the grove, although on both sides of the grove larvæ were plentiful. On the other hand, the late Dr. A. Dugés, of Guanajuato, Mexico, wrote the Chief of the Bureau, on September 8, 1900:

> I have received your very interesting study of the mosquitoes of the United States and thank you greatly for it. At the end of the book you speak of the utility of eucalyptus for driving away insects. I have had some experience with these trees. The fresh leaves placed upon the pillow will attract mosquitoes. Thinking that the mosquitoes loved this plant I had placed the branches farther away, but without result. I have burned the leaves in my chamber, and the cursed beasts have resisted the smoke.

Eucalyptus trees of many species are now grown generally all through California, and the idea that they drive away mosquitoes must be abandoned. Mr. H. J. Quayle, in Bulletin 178 of the California Agricultural Experiment Station, states that in the Burlingame section not far from San Francisco, all of the avenues are lined with eucalyptus trees and mosquitoes are most numerous where these trees are most abundant. In 1901 he captured a pint cup of mosquitoes immediately under eucalyptus trees. Coyote Point is covered with eucalyptus trees, yet the construction of a hotel on the point was abandoned on account of the abundance of mosquitoes.

Edmond and Etienne Sergent, in their antimalarial work in Algeria, had occasion to study the question of eucalyptus and published their results, together with the results of their observations and experiments upon certain other plants supposed to be deterrent to mosquitoes, in the Comptes Rendus des Séances de la Société de Biologie, November 14, 1903. With regard to eucalyptus they show that the railway station of Ouled-Rahmoun, formerly greatly troubled by mosquitoes, was visited by them much less frequently after the cutting down of great eucalyptus trees which surrounded it. The station of Ighzer-Amokran, which is isolated in the middle of a desert plain, is surrounded by a little grove of eucalyptus. Before the windows and doors were screened the rooms were visited every evening by quantities of Anopheles. The traveling Kabyles who stopped at this station would never sleep at midday under the foliage of the eucalyptus, for they said mosquitoes always came down on them. They went under the olives, where they were never bitten.

CASTOR-OIL PLANT.

During the winter of 1901 a great deal was said in the newspapers about the planting of the castor-oil plants (*Ricinus communis*) to prevent mosquitoes. These notes at that time were mainly based upon a consular report from Capt. E. H. Plumacher, United States consul at Maracaibo, Venezuela. In this report Captain Plumacher stated

that his residence is surrounded by plantain and banana trees and that he had been troubled in the past by a great number of mosquitoes which gathered in these trees. Following the example of old settlers, he planted castor seeds, which grew up in profusion, with the result that no mosquitoes were to be found among the trees, although he kept the ground well irrigated. Captain Plumacher came to Washington the following year and called on the writer April 18, 1901, bringing with him the seed of the particular variety of the castor-oil plant with which he had noted the result above stated. The seeds were planted upon the department grounds and observations indicated that mosquitoes were not at all deterred by the plants. In a report sent in from Progreso, Yucatan, September 17, 1903, United States Consul Thompson makes the following statement:

> The belief is current among the natives of Yucatan that a few castor-oil plants growing in or near a dwelling will protect the inmates from mosquitoes and certain other noxious insects peculiar to Yucatan. This belief has been to a certain extent confirmed upon experiment by me personally. My dwelling at one time seemed to be peculiarly acceptable to mosquitoes. I planted a row of castor-oil plants around the courtyard and in a short time the mosquito was as rare as he was formerly a frequent visitor. My plants were destroyed by the cyclone and now the mosquitoes are as abundant as formerly.

Some of the Venezuela seeds brought by Captain Plumacher were sent to Mr. J. Turner Brakeley, of Bordentown, N. J. He planted them in the early summer of 1901, and later in the summer observations were made with the result that mosquitoes were found both on the Venezuela plants and on other castor-oil plants. Mr. Brakeley wrote:

> The castor-oil plant is no good as a "skeetonal" protection in New Jersey. It may be a protection against the Venezuela mosquito, but it is no good where the blood pirates of New Jersey are concerned.

Giles publishes a letter sent to the Pioneer, an Indian journal, in 1901, in which the correspondent stated that he had seen a recommendation of the castor-oil plant as a deterrent for mosquitoes, and in consequence had six plants placed in pots in his room. The result was that the plants were thickly covered by the insects, which seemed "to be actually invigorated by the apparently stimulating effect of their new quarters."

The Sergents in Algeria experimented both with the castor-oil plant and with pawpaw (*Carica papaya*), on account of the reputation that these plants had as deterrents against mosquitoes. A pawpaw about 90 centimeters (3 feet) high and in good condition was inclosed in a mosquito bar of tulle, oblong in form, with its axis directed perpendicularly to the window from which the light came. In the end of the bar nearest the window they suspended a raisin grape, for food of the mosquitoes, and a little vessel of water. Then at the opposite end of the bar they put in four females of *Anopheles maculipennis* and

four females of *Culex pipiens*. They wished to see if the instinct which attracts the mosquitoes toward the light and toward an apparent way of escaping, and on the other hand the need of nourishment and water, would induce the mosquitoes to pass the middle portion of the bar which was entirely filled with large leaves of the pawpaw. At the end of four minutes one Anopheles and one Culex had passed from one end of the bar to the other; at the end of ten minutes another Anopheles and two Culex were seen to place themselves upon the pawpaw leaves and they remained there for hours. The mosquito bar was left intact for eight days. During this period the mosquitoes went everywhere and rested sometimes several hours upon the leaves and upon the branches.

An experiment exactly similar was carried on at the same time with *Ricinus communis*, with precisely similar results. When these experiments concluded at the end of eight days one Anopheles and one Culex were found dead in the pawpaw mosquito bar, and in the Ricinus bar also one Anopheles and one Culex. But in similar cages in another room during the same time six Anopheles out of twenty had died and nine Culex out of twenty-eight, in the absence of the Carica and Ricinus plants. The authors concluded that pawpaw, castor-oil plant, and eucalyptus are powerless in their effect on mosquitoes.

CHINABERRY TREES.

In spite of the statement that chinaberry trees will protect against mosquitoes, observations have failed to show the truth of the statement, and in mosquito regions people are quite as liable to be bitten while sitting under a chinaberry tree as under any other tree. Nevertheless there is an observation upon record which suggests that further experiments will be interesting. In the Public Health Reports, Vol. 21, No. 44, November 1, 1901, Dr. G. M. Corput, assistant surgeon, U. S. Marine-Hospital Service, gave the results of certain experiments conducted by hanging cans of water in the branches of different trees, including oak, pine, cherry, and palmetto. He found that in the can hung in the chinaberry bushes there were no mosquito larvæ at any time, although larvæ were found in all of the other cans.

OTHER PLANTS.

A number of plants credited with being deterrent to mosquitoes have been mentioned from time to time in the newspapers, some of the accounts being of a sensational character. The New York papers, for example, in the summer of 1906 contained numerous notices of the so-called "phu-lo" plant introduced from the Tonkin country in French Indo-China by Baron de Taillac. This plant was said to be valuable as a fodder for cattle, and to drive away mosqui-

toes. An effort was made to determine the plant, and Mr. W. E. Safford searched the literature of oriental economic botany without finding anything corresponding to it. He found that in the East Indies there is a Verbascum or mullein called "phul," the seeds of which are supposed to be narcotic, and the leaves used like those of tobacco. The leaves of this plant, although not good for general forage, are eaten by camels and goats. Assuming that this is the plant mentioned by the newspapers, there is nothing in the economic literature concerning its use as a mosquito deterrent.

Another plant which is said to act as a deterrent is a lavender known as *Ocimum viride*, a perennial which grows from 3 to 6 feet in height and occurs from Senegambia southward to Angola. Mr. A. E. Shipley [a] states that Major Burdon, resident of the Nupe Province, northern Nigeria, had given him the following account of the plant:

> A fragment of what turned out to be *Ocimum viride* was given me in August last at Lokoja, northern Nigeria, by Capt. H. D. Larymore, C. M. G., R. A., resident of the Kabba Province. Capt. Larymore's notice had been drawn to the plant by a native living in a low-lying part of the native town at Lokoja, who had told him that the natives suffered very little from the swarms of mosquitoes which existed in that part, as they protected themselves from them by the use of this plant.
>
> Capt. Larymore made inquiries and obtained a few specimens of the plant, which grows wild, though not very abundantly, in the neighborhood of Lokoja. These specimens he planted in pots and boxes and kept in and about his house. The specimens I saw were about the size of a geranium.
>
> He informed me that the presence of one of these plants in a room undoubtedly drove the mosquitoes out, and that by placing three or four of the plants around his bed at night he was able to sleep unmolested without using a mosquito net. This is very strong testimony to the efficacy of the plant, for the house in which Capt. Larymore was living is, as I had cause to know well in former years, infested with mosquitoes.

Mr. Shipley further states that E. M. Holmes in "Notes on the Medicinal Plants of Liberia" records that when chewed or rubbed the leaves of *O. viride* give off a strong odor of lemon thyme, and mentions that Doctor Roberts, of Liberia, entirely substituted the use of the plant for that of quinine in cases of fever of all kinds, giving it in the form of an infusion.

Goeldi, in Brazil, has experimented with *Ocimum minimum* without the slightest beneficial result. He also tested *Carica papaya*, a plant which has a similar reputation, but also without beneficial result. An account of the Sergents' experiments with the latter plant has just been given under the heading of the castor-oil plant.

Mr. Shipley's article in the Tropical Agriculturist was reprinted in the British Medical Journal and was quoted in many other periodicals, and in consequence many requests for seeds of *Ocimum viride* were received at the Royal Botanical Gardens at Kew from many parts of the world. About this time a report was received from Dr. W. T.

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[a] The Tropical Agriculturist, February 2, 1903, pp. 555-556.

Prout at Freetown, Sierra Leone, and was published by Sir William Thistleton-Dyer in the London Times for July 27, 1903, and in Nature, July 30, 1903. Doctor Prout's report included an account of experiments made with the "basil" plant in relation to its effect upon mosquitoes, and he concludes that his observations "appear to dispose conclusively of the plants possessing any real protective value." He showed that growing plants have little or no effect in driving away mosquitoes, and are not to be relied upon as a substitute for the mosquito net. He showed, further, that fresh "basil" leaves have no prejudicial effect upon mosquitoes when placed in close contact with them, and, further, that while the fumes of burnt "basil" leaves have a stupefying and eventually a destructive effect on mosquitoes, it is necessary, in order to produce this effect, to bring about a saturation of the air which renders it impossible for individuals to remain in the room. He thinks that cones made of powdered "basil" would, when burned, have the effect of driving mosquitoes away, and that the plant to that extent might be found useful.

PEAT.

An article in the London Times in 1908, written by an anonymous correspondent, refers to the absence of mosquitoes in swamps and marshes with peat. The writer says: "Given marshy lands and no peat, mosquitoes abound; given marshy land and peat, there are none." This article was answered by Mr. F. V. Theobald in Nature, October 15, 1908, pages 607–608. Mr. Theobald showed that he had found *Anopheles nigripes* and *Anopheles bifurcatus* breeding in the water of peat cuttings in Wales and Somerset and on the far-famed Wicken Fen numbers of *Aëdes cantans.* He stated that mosquitoes are often very abundant in the fens, even where the peat is dug. Besides the species above mentioned he has found *Anopheles maculipennis* and *Culiseta annulata* in peaty water and near peat piles in northern Wales.

WATER PLANTS.

Ordinary pools of stagnant water give birth to thousands of mosquitoes, the larvæ breeding with the greatest facility in such water. The presence of algæ and certain low forms of aquatic vegetation is evidence of the stagnation of the water, and an algal scum is frequently associated with the idea of mosquitoes in one's mind. But it is perfectly plain that where the water covering of aquatic vegetation becomes extremely dense mosquitoes can not breed, since there is no opportunity for the larvæ to come to the surface to breathe. Access to air is shut off by the dense covering of vegetation. It has often been a matter of surprise that mosquitoes are not more numerous in Holland, where the country is traversed by canals and dikes.

Mosquitoes breed there in ponds and in chance receptacles of water, but the water in the large canals is so constantly agitated by the passage of boats and by the wind that mosquitoes can not breed, and in the smaller ditches and canals the surface of the water becomes so completely covered with a continuous layer of minute aquatic vegetation (often of considerable thickness) early in the summer that there is no opportunity for the extensive breeding of mosquitoes.

Quite recently this idea has been taken up with practical ends in view in regard to antimosquito work in German colonies in Africa. It is stated in a dispatch from Consul-General Richard Guenther, of Frankfort,[a] that the director of fisheries at Biebrich, Mr. Bartmann, had found a duckweed of the genus Azolla to be especially well adapted to this use; and it was at his instance that experiments were made at the malaria station at Wilhelmshaven. It was found that the growth of the plant covered the experimental waters in a short time with a layer of about 6 centimeters, which suffocated all the mosquito larvæ below and prevented the living insects from depositing eggs in the water. Consul-General Guenther states that several years ago Director Bartmann communicated this method to the mosquito-destroying commission at Eltville on the Rhine, which has used it repeatedly with good success.

So positive were the statements published in the United States as to the results of Mr. Bartmann's work with Azolla plants that one species has been imported from Europe into the United States and will be experimented upon by the United States Department of Agriculture and by Doctor Smith, of Rutgers College. The prospects of success, however, are by no means great. One of the German officials who took part in the question of mosquito extermination in the German-African colonies is far from enthusiastic regarding the practical use of this plant, although it has been advertised on all sides in Europe and in this country. In his opinion it may possibly be of some use in special places, but so far as experiments have gone, down to the present day, the plants will not grow in dense or even moderate shade, and therefore they are of no use in the tropical forests where there are large and small pools of water—the very places where it is most needed. Moreover, the Azolla plants do not stand any great cold, nor do they stand short seasons, for which reasons their use is excluded from highland and northern regions. Further, they will not grow in brackish water and can not be utilized along seacoasts, and, still further, in case of drought they all perish and thus necessitate the restocking of dried pools and swamps.

A short statement regarding the practical use of water plants occurs on pages 1 and 2 of the fourth volume of Theobald's "Mono-

[a] Monthly Consular and Trade Reports, Bur. Manufactures, U. S. Dept. Commerce and Labor, March, 1909.

graph of the Culicidæ of the World." This statement may well be quoted:

Major Adie, I. M. S. (Ind. Med. Gaz., xxxix, June, No. 6, 1904), brings considerable evidence to bear on the benefit of *Lemna minor* as a means of keeping mosquitoes from laying their eggs on water. He shows that tanks covered with this green flat weed never contain larvæ of Culicidæ, whilst others at the same time of year are full of them.

As a test he "cleared certain areas near the banks of all *Lemna* and enclosed them with light floating structures, which were fixed enough to resist the winds—in fact, made experimental pools. I was pleased," he says, "to find in due time plenty of *Anopheles* larvæ in these pools. This seemed to prove that *Lemna* acts as a mechanical obstruction to the process of egg-laying, and a very obvious method of prevention occurred to me. Why not deliberately promote the growth of *Lemna minor* in all unavoidable collections of water to prevent the propagation of mosquitoes?"

This same green plant grows freely in England, and I have noticed a similar occurrence here. A pond close to my house was frequented by numbers of the larvæ of *Anopheles bifurcatus* and *A. maculipennis* every year. Two years ago its surface became smothered with *Lemna minor*, Linn., and *Lemna arrhiza*, Linn.; no *Anopheline* larvæ could then be found. As this was the only breeding ground near, both species have practically died out.

This small yet widely distributed genus of floating plants evidently has a very marked effect upon the frequence of culicid larvæ in natural and artificial collections of water.

The little *Lemna arrhiza*, or the rootless duckweed, occurs in Asia, Africa, South America, and Europe, and apparently has the same effect as the larger *L. minor*.

An early suggestion as to the practical use of water plants occurs in Mr. William Beutenmüller's essay on the "Destruction of the mosquito and house fly," published in Dragon-Flies *v.* Mosquitoes, The Lamborn Prize Essays, New York, 1890. Mr. Beutenmüller states that Mr. L. P. Gratacap, of the American Museum of Natural History, suggests the increase of fresh-water algæ as deterring the progress of mosquito larvæ in the water and as affecting their destruction before they can rise to the surface of the water to breathe. Mr. Beutenmüller, considering the suggestion important, stated that he believed that the vast number of fronds of Oscillatoria in the Central Park lakes, in New York City, have had a deterrent effect on the propagation of mosquitoes in the lakes. A largely disseminated mass of algæ floating through the water by its intermixed and diffused stipes he thought would seriously embarrass the development and movements of the mosquito larvæ.

The duckweeds were considered by Dr. H. P. Johnson in an appendix to Smith's New Jersey Report for 1902,[a] and by virtue of the actual small-scale experiment tried, these observations are printed in full.

While most forms of aquatic vegetation promote the breeding of mosquitoes, the Lemnaceæ, or duckweeds, are unfavorable, and in many waters almost or even wholly prevent it. These tiny plants consist merely of a floating frond, resembling a miniature lily-pad. It is circular or more frequently lobated and three to six millimeters

[a] Rep. Ent. Dept. N. J. Agr. Coll. Exp. Sta. f. 1902, pp. 565–566.

in diameter. From the under surface hang one or more roots, which never fasten in the soil, but derive their nourishment from the water. Its reproduction, mainly by division of the frond, is so rapid that in a short time (usually before July 1) it completely mantles quiet waters, notably sheltered ponds and ditches without perceptible flow. Its extraordinary abundance, often covering whole acres of shallow water, makes it an efficient protection from mosquito breeding. Wherever this plant forms a complete covering no larvæ have been found. Such places should never be treated with oil, for nature has provided a far more lasting and equally effective protection. It is probably impossible for a mosquito to lay her eggs on lemna-covered water. Even should larvæ wander in from adjacent waters, they would be unable to reach the surface for air, and would thus soon become asphyxiated. Larvæ of *Culex pungens*, injected by means of a pipette beneath the lemna in the jar * * * died in less than an hour. Where the lemna mantle is not complete, but presents interspaces of open water, larvæ of both Culex and Anopheles will usually be found in small numbers only, for lemna waters are apt to harbor the various predaceous water-bugs in great numbers.

In considering these duckweeds it should be pointed out that mosquito larvæ other than Anopheles are often found in waters well covered by them. Both Dr. H. G. Dyar and Mr. Frederick Knab have made this observation.

SMUDGES AND FUMIGANTS.

Hunters and campers have been in the habit of using almost anything that will make a dense smoke as a smudge to drive away mosquitoes. In Bermuda, fresh cascarilla bark is burned for this purpose, and elsewhere other green bark and vegetation. For household use, however, a number of different substances have been tried.

PYRETHRUM OR CHRYSANTHEMUM.

For many years finely ground powders known as Pyrethrum powder, Chrysanthemum powder, Persian insect powder, or Dalmatian insect powder have been used to kill insects. They became famous for their insecticidal effects long before their composition was known. Their use seems to have originated in Asiatic countries beyond the Caucasus Mountains. The powder was sold at high price by the inhabitants and was brought by merchants to Russia and western European countries. The nature of the powder was kept a secret until the beginning of the last century, when an Armenian merchant, Mr. Jumtikoff, learned that the powder was obtained from the dried flowerheads of certain species of composite plants of the genus Pyrethrum growing abundantly in the region now known as "Transcaucasia." The son of Mr. Jumtikoff began to manufacture the article on a large scale in 1828, and since then the pyrethrum industry has steadily grown and now the export in dried flowerheads in that part of the country is very important.

The species grown commercially in the Transcaucasian region is *Pyrethrum roseum*. The species grown in Dalmatia is *P. cinerariæ-*

folium, and the crop in Dalmatia is comparatively as valuable as the other. Thirty years ago it was considered the most valuable export in Dalmatia. The best powders are made from the dried flowerheads of these plants, and the essential principle seems to be a volatile oil that disappears with age and with exposure. Powders imported from Europe are apparently not so strong as powders made in this country from imported dried flowerheads brought over in bulk. For this reason it was, many years ago, deemed very desirable to establish a Pyrethrum-growing industry in the United States, and in 1881 the United States Entomological Commission imported and distributed the seeds of the two species above mentioned to a number of correspondents in different parts of the country. The total success was inconsiderable. Further experiments another year met with comparative failure. About this time more extensive plantations were made in California and an insect powder was made by the Buhach Producing and Manufacturing Company, of Stockton, Cal., which, being American grown and freshly ground, came into use, and is still being produced and sold under the proprietary name of "buhach," the word being supposedly derived from a slavonic word "buha," meaning flea. An article by Mr. D. W. Coquillett on the production and manufacture of this powder will be found in a bulletin [a] of this Bureau.

Most of the insect powders sold in the shops in this country have Pyrethrum powder as a basis. It is difficult to get a pure and thoroughly efficient powder. There is often adulteration. Frequently the powder made from the dried flowerheads is adulterated with powder made from the stems, or with other adulterants. Pyrethrum powders are usually used dry and are puffed or blown into crevices frequented by insects, or puffed or blown into the air of a room in which there are mosquitoes or flies. The burning of the powder in a room at night is a common practice. The powder is heaped up in a little pyramid which is lighted at the top and burns slowly, giving off a dense and pungent smoke with an odor very much like that of the Chinese punk used to light firecrackers. Often the powder is moistened and molded roughly into small cones, and after drying it burns readily and perhaps with less waste than does the dry powder. Of late years in mosquito-infested countries a number of mosquito pastilles have been sold, and many of these are molded from powders that contain more or less Pyrethrum. The efficacy of the burning pyrethrum in a close room is almost perfect. It will not actually kill all the mosquitoes, but will stupefy them and cause them to fall to the floor where they may be swept up and burned. With the windows open, however, and the constant currents of fresh air blowing through the room, this fumigation is not especially effective, and it is necessary for protection to sit in the cloud of smoke.

[a] Bul. 12, old series, Div. Ent., U. S. Dept. Agr., pp. 7–16, 1886.

The pungent odor of burning pyrethrum is not disagreeable to most people, but to some it is disagreeable, and with certain susceptible individuals it produces headache. It is apparently possible, however, to volatilize the oil without producing the actual smoke. Mr. H. W. Henshaw, of the Bureau of Biological Survey, United States Department of Agriculture, informs the writer that a few years ago a man in Hawaii patented an appliance for producing this volatilization which is all that can be wished for. The powder is placed on a brass or other metal screen above the chimney of a kerosene lamp, the idea being to dissipate the vapor of the volatile oil. According to Mr. Henshaw the effect of this method is most remarkable. "Besides being very economical in powder there is only a very slight odor perceptible and that is not at all unpleasant. The effect on the mosquitoes is immediate and all that can be wished for. They simply clear out." Another method of burning the powder that has often been employed by the writer consists in puffing it from an insufflator into a burning gas jet. This is a simple method where gas is used for illuminating purposes and produces a vapor that suffocates all mosquitoes and other insects that may be in the room.

While pyrethrum has been mainly used as a means of clearing living rooms of mosquitoes, and has ordinarily been burned in the rooms while they were occupied, it has also come into use in the extensive fumigation of houses in cases of epidemics of yellow fever, in the effort to rid houses of malarial mosquitoes, and to destroy all mosquitoes hibernating in cellars, attics, or disused rooms of residences, as well as similar hibernating mosquitoes in barns and outhouses. While reasonably effective for such purposes, it does not seem to be as effective as some of the other substances to be mentioned later and at the same time it is more expensive.

As to the quantity to be used, the regulations of the board of health of New Orleans, adopted May 25, 1903, specify the burning of 4 ounces of pyrethrum powder to 1,000 cubic feet of space; but the president of the board, Dr. Edmond Souchon, a little less than a year later wrote to the United States Marine-Hospital Service that this quantity was found insufficient for thorough work, and that 1 pound of the powder to every 1,000 cubic feet of space is necessary. As a matter of fact, however, the New Orleans board of health abandoned pyrethrum about that time, on account of the fact that the fumes do not kill mosquitoes but simply stupefy them, so that they have to be brushed up and burned. Not willing to run the slightest chance of having mosquitoes survive by escaping destruction after being stupefied, the board decided to use sulphur fumes in preference.

Nevertheless, on account of the fact that the fumes are not noxious to human beings, there still remains a decided use for pyrethrum in everyday work in mosquito-inhabited regions.

MIMMS CULICIDE.

During the yellow-fever outbreak in New Orleans in the summer of 1905 a Mr. Mimms, a chemist of New Orleans, invented a mosquito fumigant which was experimented with rather extensively and found to give good results. It was made of equal parts, by weight, of carbolic-acid crystals and gum camphor. The acid crystals were melted over a gentle heat and poured slowly over the gum, resulting in the absorption of the camphor and a final clear, somewhat volatile, liquid with rather an agreeable odor. This liquid is permanent and may be kept for some time in tight jars. In fumigation work 3 ounces of this mixture is volatilized over a lamp of some kind for every 1,000 cubic feet of space. A special apparatus for the purpose has been perfected by Dr. H. A. Veazie, of New Orleans, but a simple apparatus may be made from a section of a stovepipe, cut so as to have three legs and outlets for draft, an alcohol lamp placed beneath and a flat-bottomed basin on top. The substance is inflammable, but the vapor is not explosive. The vapor is not dangerous to human life except when very dense, but it produces a headache if too freely breathed. The writer, on the 8th of November of the epidemic year (1905), took part in the fumigation of a room containing about 1,200 feet of space in New Orleans in company with Dr. J. H. White, in charge of the public health and marine-hospital service operations in the city during the epidemic, Dr. Rupert Blue, Doctor Richardson, Dr. H. A. Veazie, and several other assistant surgeons in the service. A number of specimens of *Culex quinquefasciatus* were flying about the room. There were two boxes each about 1 foot long, with gauze slides containing one-half dozen or more mosquitoes each and a large tube of 2 inches diameter and possibly 1½ feet in length, the mouth of which was covered with mosquito bar and which lay on its side on the mantelpiece and contained several specimens of the Culex. About 6 ounces of the mixture were volatilized and the room was kept closed, without any effort to artificially stop cracks, for exactly one hour. Upon re-entering and airing the room, all mosquitoes were found to be dead and a cockroach was also found dead on the floor, having come up from between the cracks. The vapor is lighter than air, and the mosquitoes in the room unnoticed on entrance soon after fumigation sought the lower air strata of the room, gradually descending toward the floor and toward the windows, which were on one side of the room only. Sheets of manila paper had been spread before each window, and on these sheets at the end of the hour were all of the mosquitoes to be found in the room.

An account of experiments with this mixture, containing details of apparatus, etc., by Passed Assistant Surgeon Berry, of the United

States Public Health and Marine-Hospital Service, has been published.[a] The conclusions reached by Doctor Berry are as follows:

1. Culicide, in the proportion of 4 ounces per 1,000 cubic feet, used for two hours with apparatus similar to that used by us, kills *Culex pungens*, *Stegomyia*, and *Anopheles maculipennis* and temporarily stuns the house fly.

2. In the proportion of 3 ounces to 1,000 cubic feet it does not always kill the *Anopheles maculipennis*.

3. Culicide takes fire spontaneously if heated sufficiently. It is therefore necessary to keep the liquid at a certain distance from the flame; it is also better to have more than one basin in a large space, and about 8 ounces is the maximum quantity to use in one pan. All large cracks must be pasted up—the doors and windows, if loose fitting. Gummed paper spread under a window left light would be of great benefit. (I concur with Passed Assistant Surgeon Goldberger as to the closing up of large cracks, but more for preventing weakening of the strength of the gas in the room by diffusion than from any belief that insects might escape from the room.)

4. In the minds of intelligent operators, and used according to the methods employed by us, it ranks next to sulphur as an insecticide in practical fumigation.

5. Culicide vaporizes and later cools, condensing on exposed surfaces again as it cools. Whether in this way it injures articles of gilt and the like was not investigated. In practical work the only articles removed from rooms were foodstuffs and animal pets, and no complaint of injury was received. It gradually evaporates, leaving a persistent, though not disagreeable, odor.

As to the cost, with the present high prices of the ingredients of Culicide the cost of fumigating a room with 4 ounces to 1,000 cubic feet is 16 cents per 1,000 cubic feet, as compared with sulphur at 7 cents and pyrethrum at 50 cents, using 2 pounds of each of the latter per 1,000 cubic feet. The estimate does not take into consideration the alcohol used to evaporate the Culicide, but this is not much more, if any, than that used to ignite pyrethrum or sulphur pots. A further saving in favor of Culicide is that the apparatus can be easily carried in the hands from place to place. Had sulphur been used in the instances cited a wagon would have been necessary to transport the materials, which were, in the case of Culicide, conveyed in street cars. The gang would have had to be larger to move the many articles from a house necessary to be removed in sulphur fumigation, to say nothing of the larger amount of pasting to be done. Likewise, at the end of the fumigation the time required to remove the apparatus from the room is much less. For this and other reasons, if the cost of the labor is counted, I do not believe Culicide is much more expensive than sulphur, and if the cost of the articles damaged by sulphur is considered, the difference would be in favor of Culicide.

PYROFUME.

Dr. J. H. McCormack, of Mobile, Ala., has discovered that pyrofume, derived by a fractional distillation from pine wood, as a by-product in the manufacture of turpentine, is a valuable and good fumigant for mosquitoes. It is a clear liquid of a straw color; has a pungent taste, and the odor of pine woods. It is said to be harmless to mucous membranes, skin, fabrics, colors, polished metal, and painted woodwork. A report of the experiments with this substance by Passed Assistant Surgeon Francis of the United States Public Health and Marine-Hospital Service, has been published.[b]

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[a] Public Health Reports for February 2, 1906, vol. 21, No. 5, pages 83–89.

[b] Public Health Reports, June 29, 1906, vol. 21, No. 26, pp. 711–712.

A summary of Doctor Francis's experimental work follows:

1. As compared with sulphur, pyrofume stands on an equal footing in price.
2. Whereas the federal regulations require two hours' exposure to sulphur, pyrofume is efficient against mosquitoes in one hour.
3. While sulphur is injurious to metals, fabrics, paint, and colors, pyrofume leaves them unchanged.
4. Pyrofume is suitable for fumigating the engine rooms and cabins of ships, and for cars and fine residences.
5. In amounts necessary to kill mosquitoes it does not injure bananas.
6. A person can walk about in a room full of fumes and can sleep without discomfort in a room two hours after fumigation.
7. It requires only five minutes to fumigate a large room of 5,000 cubic feet.
8. The fumes are generated outside the room and conducted into it.

These conclusions were favorable, but the substance has not been taken up in the practical work of the Public Health Service on account of the fact that special contrivances necessary for the best application of the substance have not yet been perfected.

SULPHUR DIOXID.

The damage done by sulphur dioxid to household goods is the principal objection to its use as a fumigant, but in the case of yellow fever epidemics where absolutely thorough fumigation is necessary it is the most reliable of all substances to use. It was used practically exclusively in the antimosquito work during the yellow-fever outbreak of 1905 in the city of New Orleans. Suspected houses were fumigated in the most thorough way. Every effort was made to close all crevices in the rooms fumigated. Heavy paper was pasted over all apertures, including cracks. This gas is obtained by burning flowers of sulphur or lump sulphur in a small pot, fire being started with alcohol. It should be used on a bright day, and pots and polished metal and delicate things should be removed. It has been found that 2 pounds of sulphur for each 1,000 cubic feet of space will be perfectly efficient against mosquitoes and other insects. Sulphur candles may be used where available.[a]

Writing of sulphur, Giles objects to pure sulphur fumigation on account of the difficulty of burning it, and suggests a mixture of 1 part of niter and charcoal to 8 of sulphur, the mixture being made up in pastilles weighing 4 ounces each, by means of a little gum water, dried in the sun. In India he burned one of these pastilles for every 1,000 cubic feet of space and found that the effect was admirable, and that even in thatched buildings hardly a mosquito escaped. After fumigating, the floor of a bathroom in which hardly any mosquitoes could be found was covered with dead mosquitoes, which indicates not only

[a] For an excellent account of certain careful experimentation with sulphur, see an article by Passed Assistant Surgeon Francis, of the United States Public Health and Marine-Hospital Service, published in Public Health Reports, March 29, 1907, vol. 22, No. 13, pp. 346–348.

the efficacy of the fumigant, but also the effectual ways in which the Indian mosquitoes hide. He suggests that the fumigating should be done toward the end of the hibernating season, and during the heat of the day, when practically all of the mosquitoes are under shelter. He urges the adoption of this method of fumigation in all government barracks, showing that each pastille costs no more than one Lee-Medford cartridge, and that the annual bill for invaliding men who have been educated to use the latter is so heavy that it would be well to adopt any measure likely to diminish it.

In the course of the admirable work carried on during the last six years in Rio de Janeiro and which has achieved such brilliant results, it has been found that sulphur dioxid has given the best results in the disinfection of houses. Cruz has given the following account of the methods used:

The house to be disinfected was completely closed. Every opening or orifice where gas might escape was sealed with gummed paper. The furniture, too, after being thoroughly cleansed, is tightly closed. Metallic or gilded objects are protected with a covering of vaseline. After the roof is covered over with canvas the garrets are opened for the free access of sulphur gas. The canvas is fastened to the walls with lath. Then sulphur is burned in proportion of 10 to 20 grams per cubic meter, being deposited in several receptacles distributed about the house and kept clear of the floor. Each receptacle should not contain more than 1 kilogram [2.2 pounds] in order to insure complete combustion. In the vacant spaces under the roof the burning sulphur should be placed in receptacles set into others containing water to avoid danger of fire. After all the receptacles are placed, the workmen close up the only exit left open and keep the house thus sealed for not less than 2 hours. The heated air and that displaced by the sulphur gas escapes through the crevices of the roof, but the mosquitoes are kept in by the canvas covering.

In the admirable fight against the yellow-fever mosquito in New Orleans in the summer of 1905, the following directions for fumigating with sulphur dioxid were given out by the health authorities:

Remove all ornaments of metal, such as brass, copper, silver, and gilt from the room that is to be fumigated. All objects of a metallic nature which can not be removed can be protected by covering the objects tightly with paper, or with a thin coating of vaseline applied with a brush.

Remove from the room to be fumigated all fabric material after thoroughly shaking. Open all drawers and doors of furniture and closets.

The room should be closed and made as tight as possible by stopping all openings in chimney, floor, walls, keyholes, and cracks near windows and doors.

Crevices can be closed by pasting strips of paper (old newspapers) over them with a paste made of flour.

The sulphur should be placed in an iron pot, flat skillet preferred, and this placed on bricks in a tub or other convenient water receptacle with about an inch of water in the bottom. This is a precaution which must be taken to guard against accidents, as the sulphur is liable to boil over and set fire to the house.

The sulphur is readily ignited by sprinkling alcohol over it and lighting it.

The apartment should be kept closed for two hours, and then opened up and well ventilated.

NOTE.—To find the cubic contents of the room, multiply the length of the room by the width, and this total by the height, and to find the amount of sulphur necessary to

fumigate the room divide the cubic contents by 500, and the result will be the amount of sulphur required in pounds.

Take, for example, a room 15 feet long, 10 feet wide, and 10 feet high, we would multiply 15 x 10 x 10, equals 1,500 cubic feet. Divide this by 500 and you will have the amount of sulphur required, viz, 3 pounds.

After a rigid series of experimental tests, Rosenau, of the U. S. Public Health and Marine-Hospital Service, concludes that sulphur dioxid is unexcelled as an insecticide. He shows that very dilute atmospheres of the gas will quickly kill mosquitoes, and that it is quite as efficacious when dry as when moist. He shows that it has surprising power of penetrating through clothing and fabrics, and that it will kill mosquitoes even when hidden under four layers of toweling in one hour's time and with very dilute proportions. He states that although this substance has long been disparaged as a disinfectant, because it fails to kill spores, it must now be considered as holding the first rank in disinfection against yellow fever, malaria, filariasis, and other insect-borne diseases.

OTHER FUMIGANTS.

In the early antimosquito work in European cities different substances were experimented with. Fermi and Lumbao in their outlined experiments recommend chlorin gas. These writers advise that 4 or 5 spoonfuls of chlorid of lime be placed in a dinner plate and that from 5 to 10 cubic centimeters of crude sulphuric acid be poured upon it. This liberates the chlorin gas, which kills the mosquitoes. The same writers claim that the vapors of chloral act rapidly, killing mosquitoes in a few seconds. Celli and Casagrande in their early experiments in Italy recommend a substance called larycith III, which is probably a misprint for larvacide. This is dinitrocresol, a yellow aniline color, which kills adult mosquitoes when burned in small quantities. Formaldehyde gas was recommended in 1890, but has been found to have almost no insecticidal value.

Dr. John B. Smith[a] found that the powdered "jimson" weed (*Datura stramonium*) can be burned to advantage in houses. He recommends 8 ounces to fumigate 1,000 cubic feet of space. He states that it should be made up by the druggist into an amount with niter or saltpeter 1 part to 3 parts of Datura, so as to burn more freely. He states that the fumes are not poisonous to human beings, are not injurious to fabrics or to metals, and can be used with entire safety. He suggests that it be burned in a tin pan or on a shovel.

A long list of fumigants is given by Celli in his work entitled "Malaria According to the New Researches," and this list has received a critical review, which carries at the same time the results of certain experimental work by Arthur J. Kendall, in Bulletin No. 1 of the

[a] Bul. 216, N. J. Agr. Exp. Sta., p. 12, November 24, 1908.

laboratory of the board of health, Isthmian Canal Commission, Panama, 1906. Bulletin No. 2 of the same service (1906) contains an account of experiments in practical culicidal fumigation, also by Doctor Kendall.

The burning of dried orange peel has been recommended as a deterrent against mosquitoes, but there seem to be no records of conclusive experiments, although the writer has been assured of its efficacy by a Japanese physician visiting the United States.

In the course of his experiments with different disinfectants against mosquitoes, Rosenau, of the U. S. Public Health and Marine-Hospital Service,[a] did his principal work with formaldehyde and sulphur dioxid. We have mentioned his conclusions with regard to the latter substance in a previous paragraph. Formaldehyde gas, on account of its germicidal use, was early suggested against mosquitoes when their importance in the rôle of carriers of disease was ascertained, so that exact experimentation was necessary. Rosenau's results were as follows:

> Formaldehyde gas is a feeble insecticide. Mosquitoes may live in a very weak atmosphere of the gas overnight. It will kill them, however, if it is brought in direct contact in the strength and time prescribed for bacterial disinfection. For this purpose any of the accepted methods for evolving the gas is applicable, but the methods which liberate a large volume in a short time are more certain than the slower ones.
>
> Direct contact between the insects and the gas is much more difficult to obtain in ordinary room disinfection against mosquitoes than against germs, because the sense of self-protection helps the former to escape from the effects of the irritating gas. They hide in the folds of towels, bedding, clothing, hangings, fabrics, and out of the way places, where the formaldehyde gas does not penetrate in sufficient strength to kill them. The gas is polymerized and deposited as paraform in the meshes of fabrics, which prevents its penetration, and large quantities are lost by being absorbed by the organic matter of fabrics, especially woolens. In our tests whenever the insects were given favorable hiding places, such as in crumpled paper or in toweling, they quickly took advantage of the best place for themselves and thus escaped destruction.
>
> There is a striking analogy between the strength of the gas and the time of exposure necessary to penetrate the fabrics in order to kill mosquitoes and the strength and time necessary to penetrate in order to kill the spores of bacteria.
>
> Mosquitoes have a lively instinct in finding cracks or chinks where fresh air may be entering the room, or where the gas is so diluted that they escape destruction. They are able to escape through incredibly small openings. Some of the smaller varieties, such as the *Stegomyia fasciata* can get through a wire screen having 12 meshes to the inch. Therefore, formaldehyde gas can not be trusted to kill all the mosquitoes in a room which can not be tightly sealed.
>
> It was concluded that to succeed in killing all the mosquitoes in a closed space with formaldehyde gas the following definite requirements are essential: A very large volume of the gas must be liberated quickly, so that it may diffuse to all portions of the space in sufficient concentration. The room must have all the cracks and chinks where the insects may breathe the fresh air carefully sealed by pasting strips of paper over them. The room must not contain heavy folds of drapery, clothing, bedding, or fabrics in heaps or so disposed that the insects may hide away from the full effects of this gas.

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[a] Bul. No. 6 of the Hygienic Laboratory, September, 1901.

MERCURIC CHLORID.

Surg. G. M. Guiteras,[a] of the United States Public Health and Marine-Hospital Service, has recounted a series of experiments with mercuric chlorid, the use of which was first suggested to him by G. F. Matzke, steward on the American steamer *Beecham*, who told Doctor Guiteras that he had used it in the cabin of his vessel with success. Doctor Guiteras carried out a series of five experiments in a room 12 feet high by 15 feet by 13¼ feet, having a capacity of 2,385 cubic feet, sublimating the mercuric chlorid in a porcelain evaporating dish over an alcohol lamp. Mosquitoes in cages approximately containing a cubic foot of space, covered with wire gauze, were exposed at varying elevations in the room, and from 30 to 60 grams of mercuric chlorid were sublimated at exposures varying from two to three hours, at temperatures of from 77° to 88° F. Mosquitoes in the upper part of the room were invariably killed, while some of those very near the floor escaped, most of the latter, however, being killed, and the remainder never recovering perfectly except in one experiment where the temperature was only 77° F. Twenty-five grams of mercuric chlorid were found to be sufficient for 1,000 cubic feet of space. He showed that about twenty minutes are consumed in sublimating 60 grams of the chlorid; that brass work is not tarnished, and that nickel-plated work and instruments are not tarnished when wiped off immediately after fumigation. He further showed that painted surfaces are unaffected unless the chlorid is sublimated close to them and they are not immediately wiped off. Moreover, it does not affect colored silk, cotton, or woolen goods. The poisonous qualities of the substance, in Guiteras's opinion, do not constitute a real danger. When the room was opened after the experiments, he found it filled with a thick mist, but the room was entered without any especial precaution and the windows were opened. In a few minutes the vapor was carried away, leaving a slight deposit on the surfaces within the room. This was allowed to remain for two or three days, and the room was used in the meantime without any bad results. The deposit, however, should have been removed with a damp cloth, and with this ordinary care, the experimenter believes, there will be no danger in the use of the substance.

The advantages he considers to be the facility of obtaining mercuric chlorid, the small quantity necessary, and the simplicity of its use; a good alcohol lamp and a porcelain evaporating dish constitute all the machinery necessary, and its use is certainly much more convenient than sulphur, where the operators have to carry about heavy iron pots and barrels of sulphur. As to expense, he shows that at $1 per pound the 25 grams used per 1,000 feet cost somewhat less than

[a] Public Health Reports, vol. 26, No. 50, pp. 1859-1861, December 10, 1909.

half a cent, whereas 2 pounds of sulphur per 1,000 cubic feet would cost 6 cents. Moreover, it is pointed out that in practical work on a large scale the expense and trouble of hauling the disinfecting equipment from one place to another would be greatly diminished. He concludes that while mercuric chlorid can not altogether take the place of sulphur, it has a hitherto unrecognized effect, especially with reference to flies and mosquitoes.

APPARATUS FOR CATCHING ADULT MOSQUITOES.

In his important paper entitled "A Preliminary Account of the Biting Flies of India,"[a] Mr. H. Maxwell-Lefroy, imperial entomologist, describes an interesting apparatus which he used to catch mosquitoes in his bungalow. In an account published in the United States Daily Consular and Trade Reports,[b] Consul-General William H. Michael, of Calcutta, mentions this apparatus, stating it to be an invention of Mr. Lefroy. In his own account, however, Mr. Lefroy does not claim it as his invention.

He used a wooden box, lined with dark green baize and having a hinged door; the trap was 12 inches long, 12 inches broad, and 9 inches deep; a small hole, covered by a revolving piece of wood or metal, was prepared in the top of the box, and tin was placed on the floor inside. Owing to the habits of mosquitoes to seek a cool, shady place in which to rest, such as a dark corner of the room, or bookshelf, or something of the sort, they will enter this trap, which is put in the part of the room most frequented by mosquitoes, all other dark places being rendered uninhabitable, so far as possible. Mr. Lefroy writes:

> My room being open to the veranda, hordes of mosquitoes come in, and as the room is lined with bookshelves there are many desirable sleeping places. The trap stands in a shady corner, and a large number of mosquitoes enter it when they come home in the morning; the rest are usually driven out of the bookshelves either with a duster or a little tobacco smoke. Finding this desirable sleeping place untouched, they go in; the door is then slammed and fastened. At the top of the box is a small hole with a movable plate to close it; through this a teaspoonful or less of benzene is introduced and the plate put back. After a little time all the mosquitoes are dead. The box is taken to the veranda and opened there till the fumes of benzene escape.

In this way in thirty days Mr. Lefroy caught 2,336 mosquitoes—a daily average of 83.75; daily average of females, 22.68. At the same time 23 of the biting sand flies of the genus Ceratopogon were caught. He further states that whereas the inmates were before disturbed with mosquitoes and sand flies, which especially attacked the baby, the pest practically entirely ceased. All of the mosquitoes were not exterminated, but so large a portion was

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[a] Bul. No. 7, Agricultural Research Institute, Pusa, India, pp. 12–14, 1907.

[b] Dept. Commerce and Labor, Bureau of Manufactures, p. 10, March 3, 1909.

destroyed that the inmates of the house suffered no more. Mr. Lefroy goes on to say:

I am not prepared to recommend this as a universal remedy. It must be sensibly used; a small amount of personal effort in teaching a servant is necessary at first. But where mosquitoes are a plague, especially to little children, the housekeeper's thirst for the blood of the mosquitoes may rise to so great a pitch that she will welcome this device and take a delight (as we do) in counting the corpses daily.

An interesting homemade apparatus in common use in many parts of the United States is very convenient and effective. It consists of a tin cup or of a can cover nailed to the end of a long stick in such a way that a spoonful or so of kerosene can be placed in the cup, which may then, by means of the stick, be pressed up to the ceiling so as to inclose one mosquito after another. When pressed up in this way the captured mosquito will attempt to fly and be caught in the kerosene. By this method perhaps the majority of the mosquitoes in a given bedroom—certainly all those resting on the ceiling—can be caught before one goes to bed.

REMEDIES FOR MOSQUITO BITES.

It must have been the experience of most people that ordinarily little swelling and irritation result from the puncture of a mosquito where there has been no scratching or rubbing of the part. But individuals vary greatly in this respect, and it is undoubtedly true that not only do different species of mosquitoes vary in their effect, but that different individuals of the same species may also vary. The application of household ammonia has been found by many to give relief, and alcohol is also said to stop the irritation. Dr. E. O. Peck, of Morristown, N. J., finds glycerin a sovereign remedy. Touch the bite with glycerin and in a few minutes the pain is gone. Dr. Charles A. Nash, of New York City, marks the puncture with a lump of indigo and states that this instantly stops the irritation, no matter whether the application is made immediately or after the lapse of a day or so. The most satisfactory remedy known to the writer from his own personal experience has been moist soap. Wet the end of a piece of ordinary toilet soap and rub it gently on the puncture and speedily the irritation will pass away. Mr. Charles Stevenson, of Montreal, writing to the Canadian Entomologist in September, 1901, stated that he had found naphthaline moth balls to afford immediate relief from the bites of dangerous Diptera, including mosquitoes, and that a friend of his had used it successfully on flea-bites. He advises rubbing the moth ball on the affected part for a few minutes. Napththaline is also recommended by Professor Boges, director of the national board of health at Buenos Aires.

Iodin is frequently recommended for this purpose, and a note in a recent number of the Journal of Tropical Medicine and Hygiene

recommends a modification in the shape of 30 to 40 grains of iodin to the ounce of saponated petroleum, stating, "A few drops rubbed in a mosquito bite or wasp sting allay the pain instantaneously."

Rev. R. W. Anderson, rector of St. Thomas and St. Dennis, wrote us from Wando, S. C., some years ago, that he has often found that by holding his hand to a hot lamp chimney the irritation of mosquito punctures would be instantly relieved.

DRAINAGE MEASURES.

The drainage of swamp areas for agricultural or other industrial reasons needs no argument nor treatment here. The value of reclaimed swamp land for various purposes is treated somewhat in extenso in a later section, "Value of reclaimed land." The drainage of swamp areas, primarily in order to improve sanitary conditions and to reduce the annoying scourge of mosquitoes, which in itself frequently prevents the proper development of neighboring regions, is in operation and needs no argument; but it is, nevertheless, of recent undertaking. Thus, in drainage a number of things are accomplished, and where drainage is accompanied by filling, still other results are to be reached. Drainage on a small scale for the purpose of doing away with mosquitoes has been practiced for a long time. In "Mosquitoes," page 198, the writer shows how, by an expenditure of $40 for drainage in the summer of 1900 in a Maryland village, malaria practically ceased to exist, although the previous summer there had been one or more cases in every family in the district.

One of the editors of the Scientific American, Mr. Frederick K. Beech, is quoted (loc. cit., pp. 208–209) as follows:

> In the town of Stratford, Conn., where I have resided for the past forty-five years, we have been greatly plagued by swarms of mosquitoes, so great, in fact, that the "Stratford mosquito" became a well-known characteristic of Stratford. We have in the southern part of our town, bordering on the sound, several acres of marsh land or meadow, which would become periodically overflowed with water in the summer and a tremendous breeding ground for mosquitoes, and this plague to the town continued until about 1890–91, when a party from Bridgeport, Conn., purchased a large section of the meadows and began to protect them by a dike, both on the north and south ends, which shut out the water. In addition to this, numerous drain ditches were made which helped to carry the water away. The result of this work made the land perfectly dry and spongy, so that after a rain no pools collected on the surface of the meadow and the creation of the mosquitoes was prevented. The transformation was so remarkable that people outside the town would hardly believe that it had been effected, and a year or two later the town voted a special appropriation of $2,000 to the party who undertook to build the dike and render the meadows mosquito-proof. It had also the effect of placing on the market a large tract of land elevated from the sound, for residences, and as many as twenty-five summer residences have been built upon this land bordering on the sound, and the number is increasing each year. They are free from mosquitoes, so that the operation shows the economy and the benefit that will result by using some means for eliminating the mosquito-breeding pools.

A great deal of valuable drainage work has been done in the past few years in the salt marshes of the North Atlantic coast, and there is one instance of this on the Pacific coast, with the direct idea of doing away with the salt-marsh mosquitoes, several species of which occur in such localities, all having unusual power of flight and being able to proceed inland for many miles, thus annoying the inhabitants of a large extent of country. One of the first operations of this kind was conducted by the wealthy owners of Center Island, off the north coast of Long Island, in Long Island Sound. This work led to the somewhat elaborate work under the organization known as the North Shore Improvement Association, referred to elsewhere, which included simple operations over a considerable distance along the north shore of Long Island and in the vicinity of Oyster Bay. These operations took place in 1902 and 1903. Later some excellent work was done at Lawrence, Long Island, and the following account, taken from the "Report of the New York State Entomologist," Dr. E. P. Felt, for 1905, gives an excellent idea of methods and results:

A most striking illustration of this work is that given by Lawrence, L. I., which has amply demonstrated the feasibility of controlling the salt-marsh mosquitoes by relatively simple and comparatively inexpensive ditching operations. The annual expense is only about $1,000 and the total expenditure on these operations during the past four years does not exceed $10,000, in spite of the fact that the village is situated upon a narrow neck of land with the extensive salt-marsh areas of Jamaica Bay to the north and west and large marshes south and east, all producing in former days millions of mosquitoes, which invaded the village in swarms with every favorable breeze. Some of these marshes extend almost to the center of the village, which is so completely surrounded that a journey of 2½ miles in almost any direction will bring one to a salt marsh. More unfavorable conditions for mosquito control could hardly be found, and before this work was attempted mosquitoes swarmed in the village in May and remained in numbers most of the season. The second year swarms did not invade this territory till June, and last year it was the first of July before they appeared. Our investigations at the end of last July showed that there were practically no mosquitoes in the center of the village. It was our privilege to sit on a piazza one evening when conditions were most favorable for mosquito activity. Though it was cloudy with only a little breeze, and rather warm, not one appeared. Previous to this antimosquito work it was said that one could not sit on this piazza without being covered with netting, and the owner even went to the trouble of making a framework to hold netting to suspend over individual chairs, so that his family and guests could sit in comfort.

This very desirable result has been brought about by a draining system so planned that the entire length of all the ditches will be flushed by every tide. The general practice is to run these ditches within about 200 feet of firm ground and sometimes closer, making them 18 to 24 inches in width, from 2 to 3 feet deep, with main ditches here and there to tidal channels. A few headland ditches are run into the more dangerous swampy areas in baylike extensions of the marsh. Such ditches require no surveying and cost only 1½ cents a running foot. A little experience enables one to lay them out properly and the tides make the determining of levels extremely easy. It was very interesting to compare the conditions between ditched areas and undrained marshes. The former were so free from mosquitoes that one could tramp upon them with practical immunity from bites, though occasionally a few mosquitoes were seen on one's person. No larvæ were found, and in fact there were very few places where

breeding was possible. Undrained marshes presented a very different condition. Mosquitoes swarming in adjacent woodlands made driving very uncomfortable, and when on the marshes one was attended by considerable swarms of vicious biters, even in midday. Here and there breeding pools were literally black with young wrigglers. This contrast between drained and undrained areas would doubtless have been much greater were it not for the fact that our inspection was made during such a dry time that even undrained marshes presented comparatively few favorable breeding places.

Experience at Lawrence has shown that deep ditches with perpendicular sides are far more permanent than shallow ones with sloping sides. The attempt to slope the bottom of the ditch so that all the water will drain out invariably results in depressions which may become dangerous breeding places and the drainage value of the ditch is much lessened. Sloping sides afford opportunity for the growth of grass and sedges with the result that the ditch soon becomes choked with vegetation. The deep perpendicular ditches described above remain entirely free from vegetable growth, and with a little care in removing sods and drifting matter will last for years. Some dug four years ago were in perfect condition last July, though the grass growing along the sides overhung and almost hid the ditch from view in places. An area of 25 feet on each side is easily drained by such a ditch. The village now has 40 miles of marsh drains, which require more or less attention from three men during most of the open season. They keep the ditches clear, supplementing their work by judicious oiling here and there wherever mosquito larvæ are abundant, and then have considerable time available for perfecting the system and ditching more distant marshes. Experience showed that a considerable number of salt-marsh mosquitoes bred on that portion of Jamaica Bay northwest of the village were brought in by southwest followed by northeast winds. This led to the extension of ditching operations some 2 miles beyond the village limits. The work in the immediate vicinity of Lawrence was done partly at public expense assisted by contributions from owners benefited, though it was impossible to secure the cooperation of persons owning the distant marshes, which latter were drained entirely at village expense. The existence of such breeding areas is an imposition upon adjacent communities, and it is only a question of time before public opinion will demand a law either compelling owners to abate such nuisances or else provide for their suppression at public expense. The money invested by Lawrence in this work, a total of less than $10,000, has amply justified itself in vastly improved conditions. The village and its vicinity have been entirely freed from breeding places, although it is subject to late summer invasions by hordes of mosquitoes when favorable winds bring them from undrained marshes. Even this will be obviated when the value of the work becomes more generally appreciated, and then the cost of the operations will be amply returned in increased land values, to say nothing of the satisfaction accruing from the absence of these dangerous and annoying pests.

On the north shore of Long Island, in Connecticut, and especially in the vicinity of New Haven, certain simple ditching operations have been carried on which have resulted, at a comparative inexpense, in a very considerable reduction of the mosquito supply.

THE CALIFORNIA WORK.

In California, in connection with work carried on by the California State Agricultural Experiment Station, in 1905, some excellent work was done under the auspices of the Burlingame Improvement Club, in San Francisco, under the direction of H. J. Quayle, of the California Experiment Station. The territory involved is included in the upper portion of the San Francisco Peninsula, extending from South San

Francisco on the north to San Mateo on the south, a distance of about 10 miles. The salt-marsh area included consisted of a narrow strip along the San Francisco Bay shore, varying from one-half to 2 miles in width and 10 miles long. No part of the area was continually covered with water, and it is all above the lowest high tide. The higher tides, however, particularly those accompanying full moon, almost completely submerge the area. The operations, as described,[a] are quoted as follows:

What was done on the marsh.—The actual work of control was commenced February 27, when a gang of men was started to work at ditching on the salt marsh. This work was started near the Blackhawk dairy, where the marshes begin north of Burlingame, it being the intention to work northward toward San Bruno, and make the work permanent as far as we would be able to go in a single season. However, the work went rapidly and the troublesome areas north of Millbrae were not so numerous as was figured, and consequently practically the whole area was covered during the past season.

The ditching in the Blackhawk area consisted in connecting the pools and areas of standing water with the tidal creeks in order that they might drain more rapidly and before a brood of mosquitoes would have time to develop. The largest of these ditches were 12 inches wide and about 15 inches deep, and these served as main channels into which smaller laterals were cut. These laterals, and, indeed, the greater part of all of the ditches, were but one spade wide, and one or two spades deep, according to the depth of the pool to be drained. Only where the pools were very large and a great quantity of water to run off in a short time was it necessary to make larger ditches. By "a spade" here is meant the common California spade, which is about 6 inches wide and 10 inches high. The eastern drain spade has not yet found its way to California; undoubtedly it would be preferable for the deeper ditches in this kind of work. In addition to the well-defined pools, there was a considerable area in the Blackhawk region which was covered with but a few inches of water for a considerable time after each high tide, and before the rains ceased in the spring water stood over this area almost continuously. Such areas had to be treated by making a number of parallel ditches from 50 to 75 feet apart, in order to permit of sufficiently rapid drainage. Rather extensive ditching was done here to make the area safe while the rains were still continuing, while later in the season, when the rains ceased, it would have been safe with much less ditching. Small pools that were far from tidal creeks were made safe by filling in rather than draining. The size of the pool, and the length of ditch necessary to drain, will determine which of the methods is to be followed. In this way the marsh area was gone over, doing away with all the places where larvæ were found or were likely to be found for a distance of about a mile along the bay northward, where the diked area was met with.

This part of the marsh presented a more difficult problem. The dike, having been neglected for ten or twelve years, was in poor condition, and there were several breaks in the upper end near Millbrae. The gates were not in working order, and their floors were too high to drain the area enclosed.

The breaks in the dike at the upper end permitted the water to back up at the opposite side, and this, together with the fresh water from the hills, kept the water level, at almost high tide, over a large part of the area. To make matters worse, the dike, just after it was built, was in effective operation just long enough to thoroughly dry the ground and cause it to crack. These cracks, which are 4 or 5 inches wide and 2 or 3 feet deep, still exist, forming a complete network over most of the area. Mosquitoes were found breeding in this area, and it was next to impossible to get over the ground,

[a] Bul. 178, Univ. of Cal. Exp. Sta., pp. 15–21, 1906.

even with waders. A considerable part of the area was submerged to the depth of a foot or more, thus concealing from view the cracks and tidal creeks, which one was likely to fall into at every step, and which made any attempt at rapid progress somewhat discouraging.

It was at once evident, under these conditions, that if the area was to be controlled, the dike must be either cut through in a number of places in order to allow a freer circulation of water, or the breaks must be repaired and the gates put in operation, and the water kept out. The latter scheme was the one followed, because it would be possible to make the area thoroughly dry, and thus the results would be more certain. In attempting to operate the gates we were made to appreciate the effect of a ten or twelve years' coating of rust on the large screws by which the gates were manipulated. After the gates were put in operation the breaks in the dike were repaired and the weak places strengthened. The largest break repaired was immediately joining the upper gate. This was 30 feet wide, and by the action of the water had worn down so that at high tide there was a depth of 10 feet of water. A double wall of sheet piling about 6 feet apart was sunk here and the space between filled in with earth. The other breaks were repaired by sinking a single wall of sheet piling in the center and filling in on both sides with dirt.

After these repairs were completed the gates were operated, opened at low tide and closed at high tide, for a week, but at the end of this time there was still much water in the area, because the gate floors were not low enough to lower the water level sufficiently. This made it necessary to lower the gate floors and add an extension to the gates to reach the lower level. This being done the gates were again operated for several days, but it was found that, due to seepage of water through the dike in many places, hand operating would have to be kept up almost indefinitely. It was therefore necessary to replace these old-style gates, operated by hand, by automatic ones, and these were, consequently, put in at both the upper and lower gates, and the floors lowered 32 and 20 inches, respectively. These gates were made to swing on an axle at the top, the lower end being free and easily moved by the pressure of the water, so that at low tide it was opened by the pressure of water on the inside, and closed as the water from the high tide rose on the outside.

This tidal creek, which served as an outlet for the lower gate, had become filled in to a depth of 2 or 3 feet during the period the gate was closed, and this was cleaned out for 300 or 400 yards toward the bay in order to drain out the area enclosed by the dike.

With this work done upon the dike the area enclosed by it was treated in much the same way as that outside, except that the network of cracks, already mentioned, had to be filled in in many places, and several of the tidal creeks deepened. The reward for all this work came later in the season when the area was changed from a veritable breeding ground to the safest portion of the marsh. Indeed, this area was the key to the situation, and the excessive abundance of mosquitoes in this particular territory was without doubt due to this extensive breeding ground.

It is appropriate to mention here the connection of this work with the reclamation of marsh lands. This tract of 500 or 600 acres, which had been useful only for duck hunting, is now thoroughly dry and could be put to agricultural uses at very little additional expense. Such work has already been extensively taken up on the marshes below San Mateo, and it had been found that a good crop of grain can be raised on such land in the second year of its cultivation. It is safe to predict that all the marsh land involved in the present campaign will be under cultivation before many years, and because of its proximity to the metropolis of the coast should be very valuable.

Besides the marshes already mentioned, permanent control work was done on the marsh about Millbrae and northward to San Bruno, and also some drainage work at Coyote Point, opposite San Mateo. The work at these places was much the same as that already described, and further details are unnecessary.

In addition to this permanent work, there was some oiling done on the marsh where the ditching and filling work were not rapid enough to keep ahead of a developing brood. The total amount of oil applied, however, did not exceed 400 gallons, and most of this was applied to the large tidal creeks in the reclaimed land opposite San Mateo. The remainder was applied to pools where wrigglers appeared after a high tide, and, the brood being checked, we had until the next high tide in which to make the pools permanently safe.

During 1908, 200 acres of salt-meadow land on the shore of Little Neck Bay, between Bay City and Douglaston, Long Island, were drained by simple ditching measures. This work was done at the instigation of the Bay Side Park Association and the Douglaston Civic Association, both associations forming a joint committee to exterminate mosquitoes. They went to the board of health of Flushing and enlisted its aid under a new law which permits the board of health to enforce the drainage of mosquito-breeding places. The board of health issued its orders to the owners of the meadow lands, commanding them to drain their properties within ten days. The movement was most successful, and by October 24, 1908, 75 miles of ditches had been dug on the Flushing meadows, and the work was still going on.

As early as 1900 excellent antimosquito work was done on Staten Island, New York, by the Richmond County Club, under the leadership of Mr. W. C. Kerr, in the course of which considerable drainage of fresh-water swamps above the seacoast places was carried on with great success and at a minimum of expense. This work, accompanied with the use of kerosene on the larger ditches, resulted in complete relief from the attacks of the fresh-water mosquitoes, which during the early summer had previously been always numerous and ferocious. But, down the bluffs, below the cliffs, there was a large area of salt marsh, and in the higher portions of this marsh land the salt-marsh mosquitoes bred abundantly and flew up the bluff in swarms to take the place of the fresh-water mosquitoes. An attempt was made, by members of the club, to buy this land and drain it, but they were unsuccessful. A few years later the meadow was taken up by Doctor Doty, the health officer of New York, who eventually began drainage measures, which have been carried out with persistence and effect. Some of the most effective of any drainage work has been done in the course of these operations.

THE NEW JERSEY WORK.

The most interesting and probably the most important work of this character that has been done anywhere in the world was perhaps that undertaken by the State of New Jersey. The writer, in an address on "The Recent Progress and Present Conditions of Economic

Entomology," delivered before the Seventh International Zoological Congress, Boston, August, 1907, made the following statement:

But the work done by Smith, in New Jersey, and that which he has under way in his large-scale campaign against the mosquitoes of that State, are of such a unique character that they force special mention. The mosquito destruction measures carried on by English workers, and especially by those connected with the Liverpool School of Tropical Medicine, in different parts of the Tropics controlled by England, have been large-scale work of great value. That done by the army of occupation in Cuba was of enormous value, so far as the city of Havana was concerned, and an assistant just returned from the Isthmian Canal Zone assures me that it is possible to now sit out-of-doors of an evening upon an unprotected veranda anywhere in the Zone without being annoyed by mosquitoes, and without danger of contracting malaria or yellow fever.

These are all great pieces of work, but when we consider the condition that exists in the State of New Jersey, and the indefatigable and successful work of Smith in the handling of the most difficult problem of the species that breed in the salt marshes, and of his persistent and finally successful efforts to induce the state legislature of that wealthy but extremely economical State to appropriate a large sum of money to relieve New Jersey from its characteristically traditional pest—we must hold up our hands in admiration.

Chapter 134, of the Laws of 1906 for New Jersey, which went into effect on November 1, 1906, the passage of which was largely due to the efforts of Doctor Smith, is so interesting and important in this connection that it is quoted in full, to wit:

AN ACT to provide for locating and abolishing mosquito-breeding salt-marsh areas within the State, for assistance in dealing with certain inland breeding places, and appropriating money to carry its provisions into effect.

Be it enacted by the senate and general assembly of the State of New Jersey:

1.—It shall be the duty of the director of the state experiment station, by himself or through an executive officer to be appointed by him to carry out the provisions of this act, to survey or cause to be surveyed all the salt-marsh areas within the State, in such order as he may deem desirable, and to such extent as he may deem necessary, and he shall prepare or cause to be prepared a map of each section as surveyed, and shall indicate thereon all the mosquito-breeding places found on every such area, together with a memorandum of the method to be adopted in dealing with such mosquito-breeding places and the probable cost of abolishing the same.

2.—It shall be the further duty of said director, in the manner above described, to survey, at the request of the board of health of any city, town, township, borough, or village within the State, to such extent as may be necessary, any fresh-water swamp or other territory suspected of breeding malarial or other mosquitoes, within the jurisdiction of such board, and he shall prepare a map of such suspected area, locating upon it such mosquito-breeding places as may be discovered, and shall report upon the same as hereinafter provided in section eight of this act. Requests as hereinbefore provided for in this section may be made by any board of health within the State, upon its own motion, and must be made upon the petition, in writing, of ten or more freeholders residing within the jurisdiction of any such board.

3.—Whenever, in the course of a survey made as prescribed in section one of this act, it is found that within the limits of any city, town, borough, or village there exists points or places where salt-marsh mosquitoes breed, it shall be the duty of the director aforesaid, through his executive officer, to notify, in writing, by personal service upon some officer, or member thereof, the board of health within whose jurisdiction such breeding points or places occur, of the extent and location of such breeding

places, and such notice shall be accompanied by a copy of the map prepared as prescribed in section one, and of the memorandum stating the character of the work to be done and its probable cost, also therein provided for. It shall thereupon become the duty of the said board, within twenty days from the time at which notice is served as aforesaid, to investigate the ownership, so far as ascertainable, of the territory on which the breeding places occur, and to notify the owner or owners of such lands, if they can be found or ascertained, in such manner as other notices of such boards are served, of the facts set out in the communication from the director, and of the further fact that, under chapter sixty-eight of the laws of one thousand eight hundred and eighty-seven, as amended in chapter one hundred and nineteen of the laws of one thousand nine hundred and four, any water in which mosquito larvæ breed is a nuisance and subject to abatement as such. Said notice shall further contain an order that the nuisance, consisting of mosquito-breeding pools, be abated within a period to be stated, and which shall not be more than sixty days from the date of said notice, failing which the board would proceed to abate, in accordance with the act and its amendments above cited.

4.—In case any owner of salt-marsh lands on which mosquito-breeding places occur and upon whom notice has been served as above set out, fails or neglects to comply with the order of the board within the time limited therein, it shall be the duty of said board to proceed to abate under the powers given in sections thirteen and fourteen of the act and its amendments cited in the preceding section, or, in case this is deemed inexpedient, it shall certify to the common council or other governing body of the city, town, township, borough, or village the facts that such an order has been made and that it has not been complied with, and it shall request such council or other governing body to provide the money necessary to enable the board to abate such nuisance in the manner provided by law. It shall thereupon become the duty of such governing body to act upon such certificate at its next meeting and to consider the appropriation of the money necessary to abate the nuisance so certified. If it be decided that the municipality has no money available for such purpose, such decision shall be transmitted to the board of health making the certificate, which said board shall thereupon communicate such decision forthwith to the director of the agricultural experiment station or his executive officer.

5.—If, in the judgment of the director aforesaid, public interests will be served thereby, he may set aside out of the moneys appropriated by this act such an amount as may be necessary to abate the nuisance found existing and to abolish the mosquito-breeding places found in the municipality which has declared itself without funds available as prescribed in the preceding section. Notice that such an amount has been set aside as above described shall be given to the board of health within whose jurisdiction such mosquito-breeding places are situated, and said board shall thereupon appoint some person designated by said director or his executive officer a special inspector of said board for the sole purpose of acting in its behalf in abating the nuisance found to be existing, and all acts and work done to abate such nuisances and to abolish such breeding places shall be done in the name of and on behalf of such board of health.

6.—If in the proceeding taken under section four of this act the common council or other governing body of any municipality appropriate to the extent of fifty per centum or more of the money required to abate the nuisance and to abolish the mosquito-breeding places within its jurisdiction it shall become the duty of said director of the agricultural experiment station to set aside out of the moneys herein appropriated such sum as may be necessary to complete the work, and in all cases preference shall be given, in the assignment of moneys herein appropriated, to those municipalities that contribute to the work and in order of the percentage which they contribute; those contributing the highest percentage to be in all cases preferred in order.

7.—In all cases where a municipality contributes fifty per centum or more of the estimated cost of abolishing the breeding places for salt-marsh mosquitoes within its

jurisdiction, the work may be done by the municipality as other work is done under its direction, and the amount set aside as provided in section six may be paid to the treasurer or other disbursing officer of such municipality for use in completing the work; but no payment shall be made to such treasurer or other disbursing officer until the amount appropriated by the municipality has been actually expended, nor until a certificate has been filed by the director or his executive officer stating the work already done is satisfactory and sufficient to obtain the desired result, and that the arrangements made for its completion are proper and can be carried out for the sum awarded.

8.—In all investigations made under section two of this act the report to be made to the board of health requesting the survey shall state what mosquitoes were found in the territory complained of, whether they are local breeders or migrants from other points, and, in the case of migrants, their probable source, whether the territory in question is dangerous or a nuisance because of mosquito breeding, the character of the work necessary to abate such nuisance and abolish the breeding places, and the probable cost of the work. Said board of health must then proceed to abolish the breeding places found under the general powers of such boards, but if it shall appear that the necessary cost of the work shall equal or exceed the value of the land without increasing its taxable value, such board may apply to the director aforesaid, who may, if he deems the matter of sufficient public interest, contribute to the cost of the necessary work, provided that not more than fifty per centum of the amount shall be contributed in any case, and not more than five hundred dollars in any one municipality.

9.—All moneys contributed or set aside out of the amount appropriated in this act by the director of the agricultural experiment station in accordance with its provisions shall be paid out by the comptroller of the State upon the certificate of said director that all the conditions and requirements of this act have been complied with, and in the case provided for in section five payments shall be made to the contractor upon a statement by the person in charge of the work, as therein prescribed, attested by said director, showing the amount due and that the work has been completed in accordance with the specifications of his contract.

10.—For the purpose of carrying into effect the provisions of this act, the said director of the state agricultural experiment station shall have power to expend such amount of money, annually, as may be appropriated by the legislature; *provided*, that the aggregate sum appropriated for the purpose of this act shall not exceed three hundred and fifty thousand dollars. The comptroller of the State shall draw his warrant in payment of all bills approved by the director of the state experiment station, and the treasurer of the State shall pay all warrants so drawn to the extent of the amount appropriated by the legislature.

11.—This act shall take effect November first, one thousand nine hundred and six.

Approved April 20, 1906.

This law was drafted only after the most careful observations by Doctor Smith and his assistants, and after they had made themselves perfectly familiar with the conditions existing in the salt-marsh area in New Jersey and with the exact life histories of the different species of mosquitoes involved, and also after preliminary drainage work had been undertaken and carried to successful conclusion over part of the area without the assistance of state funds.

Doctor Smith had found that three species, of approximately similar habits, develop in the salt marshes of New Jersey and migrate inland for long distances—up to 40 miles in some instances—thus making local work on the part of inland communities by no means

perfectly efficient. Citizens' organizations had, for example, done excellent work in the way of destroying household and other fresh-water breeding mosquitoes, in South Orange, Summit, and other inland towns; but occasional inland migrations of swarms of salt-water species necessitated the retention of house screens and discouraged the community workers. The salt-marsh species Doctor Smith found to be *Aëdes cantator*, *A. sollicitans*, and *A. tæniorhynchus*. The former is the more northern and earliest, forming the bulk of the specimens on the marshes north of the Raritan River. South of that point *cantator* makes an early brood only and *sollicitans* is the abundant species during the rest of the season until late fall, when *cantator* sometimes reappears. He finds that *tæniorhynchus* is never so common as the others and is a midsummer species. It was a most important discovery when Doctor Smith and his assistants found that all of these species laid their eggs in the marsh mud, and that these eggs may retain their vitality for three years, even if repeatedly covered with water. He found that every time a marsh becomes water-covered some eggs hatch, and if the water remains long enough the larvæ reach maturity. On account of the possible long duration of the egg stage the problem seemed to be to permit or even favor the hatching of all of the eggs, and then to provide for the removal of the water so rapidly that none of the larvæ could come to maturity.

To accomplish this end a system has been developed by which the force working under the state entomologist makes deep, narrow ditches in the salt-marshes by means of special machinery. These ditches are 30 inches deep and 10 inches wide, the sides being perpendicular. The upper 12 or 18 inches of the ordinary salt marsh is peat or turf, and the water drains readily from it. Below this peat is sand, mud, or clay; and at 30 inches a depth has been reached which is below high-water mark and below the point at which vegetation is likely to start. The ditches are placed from 50 to 200 feet apart, depending upon the character of the marsh, but more often 200 feet apart than less.

Anticipating the ultimate passage of a state bill, work of this character was begun on the Shrewsbury River in 1902, and at the present time both shores are now drained to the full length of the river. In 1903–1904 the marsh areas belonging to the cities of Elizabeth and Newark were drained at the expense of the cities, and in 1906 systematic drainage work was begun at the Hackensack marshes and continued along the shores of Middlesex and Monmouth counties, along both shores of the Raritan River, and along the numerous small rivers and creeks running into the Newark and Raritan bays and into the Arthur Kill.

During the year 1906, and in the preceding experimental work, 4,900 acres of marsh land were drained and 710,000 feet of ditches were put in. During the season of 1907, 10,951 acres of territory were cleaned up and 1,505,524 feet of ditching were put in. During the season of 1908, 6,669 acres of marsh land were dealt with and 888,650 feet of ditching was made. Out of the 1909 appropriation 2,672 acres of marsh were drained with 329,800 feet of ditching. This gives a grand total of 25,192 acres of marsh land and 3,633,974 feet of ditches.

The area extends from the Hackensack at Secaucus to the mouth of Toms River on Barnegat Bay, a distance of nearly 70 miles of shore line. In addition there are about 10 miles on Long Beach in which experimental work was done among the sand hills, in the pockets where the marsh mosquitoes bred whenever there was a storm or a storm tide to fill them. Here no ditches could be made because the layer of turf was very thin and below it was sand. Nor could outlets be obtained to tidewater without the expenditure of disproportionately large sums.

The smaller depressions were filled with brush held in place by a layer of sand, and this served to gather and hold the blowing sand in high winds, causing a complete filling after a year or two. The larger depressions were drained to a center where a pond varying from 6 to 15 feet square was dug 3 or 4 feet deep and a large barrel sunk into the center. This brought the line down below the level of the bay and kept water permanently present; in fact, there was an appreciable rise and fall of water with the tides, and it gave outlet to all the water that drained naturally to these low points. Ditches were dug along the natural drainage lines to these ponds, and the latter were then stocked with killies (*Fundulus* sp.). Some of these pools are now three years old, and the fish have multiplied. Altogether this plan has worked well and required little looking after.

As to the amount expended, the state appropriations make a total of $58,500. About $10,000 has been spent by various municipalities, and probably $75,000 would cover what has been spent in marsh-mosquito work in New Jersey, counting in the local improvements made. This includes also the cost of administration since 1905.

The total estimated cost of the marsh work in the State is $350,000, and up to date the cost of the work actually done is within the amount estimated for that work.

The work has been entirely original in its character, from the beginning of the observations upon the most unexpected habits of the insects, through the development of special machinery, and the ascertaining of the important fact that this simple and very rapid and economic form of drainage meets the important requirement of stopping the breeding of these extremely annoying migratory forms.

The writer has visited the marshes, has seen the excellent results of the work accomplished, and has watched the active operation of digging the ditches. It is possible to walk with dry feet over the drained marshes, and the crop of hay the first year after ditching doubles in quantity.

A bit of work excellent in its results and very economical in its cost, in the way of the drainage of an upland marsh, is described by Doctor Smith in his report for 1908. A new normal school was about to be constructed on Montclair Heights, and there were swampy areas near by which a committee of the state board of education considered to be dangerous as mosquito-breeding places. Doctor Smith caused an inspection to be made early in April, and found that there was a danger point in which not only the ordinary pool mosquitoes but malarial mosquitoes could develop. At a cost of $250, 3,000 feet of ditching was placed or improved, and all the surface water was drained to a culvert through a railroad embankment. The heavy rains of May gave excellent opportunity for testing the effectiveness of the work, and no mosquito breeding was found there throughout the season.

THE VALUE OF RECLAIMED LANDS.

GENERAL RECLAMATION WORK.

The general value of lands reclaimed from swamps is obvious. Practically all of Holland has been reclaimed from the sea. Large areas of the most valuable farming land in the world have been reclaimed from nonproductive swamps. To the nonproductiveness of swamp land must be added the great danger that exists in its continuance through the invariable presence of disease-bearing mosquitoes. The drainage of swamps not only destroys unlimited breeding places of mosquitoes, but vastly increases the value of the land for farming purposes and for other utilitarian uses. Either reason amply pays for the operation. The late Prof. N. S. Shaler, in his report to the North Shore Improvement Association, showed that fields gained by marsh drainage possess the greatest fertility and their endurance to cropping without manuring exceeds that of any other agricultural land except possibly arid regions which are irrigated. The range of crops is great and includes all ordinary farm and garden crops except in some places Indian corn. Reclaimed swamp lands are especially adapted for truck farming, because it is easy to maintain the level of underground water where the roots of the plants can reach it. Professor Shaler shows that the larger part of the best irrigable land in Holland, and much of that in Belgium, northern Germany, and eastern England has been gained from what was originally tidal fields. He estimates not less than 10,000 square miles in those countries to have been redeemed in this way.

The only large example of diked and improved marshes in the northeastern United States is at Green Harbor, Mass., where 1,200 acres have been won to tillage, about one-half being used for hay fields and the other for different crops. The result obtained in the farming of this land is excellent. Asparagus has produced large crops continuously for more than twenty years without the use of any fertilizer.

Prof. Milton Whitney, Chief of the Bureau of Soils, of the United States Department of Agriculture, some years ago drew up the following statement at the request of the writer, concerning the value of reclaimed swamp land:

Swamp lands, by virtue of their position, become the repository of highly fertile material washed from the uplands by the rains. As a general rule, the immediate surface of any soil is the most fertile portion of that soil, resulting from the fact that this surface material is in physical condition, and most exposed to the action of the weather, the sun, rains, and air. This surface is the first portion removed during rains, and is the portion carried down into the swamps and deposited. When erosion goes on at such a rapid rate that both the surface and the underlying raw soil are washed away, the resulting bottom land deposit is frequently sterile. Witness the mud flats and swamps along the Sacramento River, in California, which have been covered with mud from the hydraulic mines of the Sierra Nevadas. Here large areas have been ruined by the mud, and will not become fertile until the weather has acted upon the material long enough to make the soil an acceptable medium for plant growth. Fortunately, most of our lowlands and swamps receive only the more gentle washing or the most fertile materials from the uplands.

Swamp lands contain an unusual amount of organic matter, and for that reason are easy to maintain in proper tilth, light to work, and warm. From their low position, water is generally abundant, or easy to obtain for irrigation by pumping or diversion from nearby streams.

Swamp lands and tide marshes are considered the most valuable of lands in the world's older countries. Their inherent fertility is recognized, and the ease with which they are cultivated and irrigated is greatly appreciated. In England for two hundred years the tide lands have been under reclamation, and to-day over 1,000,000 acres are in a "matchless state of fertility."

In Holland extensive areas have been reclaimed from the sea. The greater part of the country lies at or below the level of the sea, and is reclaimed from a jungle of swamps and savannas. Holland to-day represents one of the most successful attempts at swamp reclamation. Lakes have been drained by diking and pumping, and plans are now on foot to drain the Zuyder Zee, an arm of the ocean.

In our own country swamp reclamation has been carried out on a large scale in the Middle Western States. Ohio, Indiana, Illinois, Michigan, and Wisconsin have great areas of productive land once swamp but now the most fertile and reliable land in those States. The tide marshes around Puget Sound, in Washington, have been lying untouched until within the last few years, but the recent great influx of Scandinavians has resulted in a movement toward the reclamation of these lands, and excellent farms are being established.

In California one of the greatest areas of swamp peat land in the world lies in the Sacramento-San Joaquin Delta. Over 1,500,000 acres of peat from 6 to 40 feet thick are ready for reduction in productive capacity, and to-day large areas are being reclaimed. Yields of 500 bushels of potatoes, 6,000 pounds of asparagus, 60 bushels of barley and oats have been common, and with proper farming such yields should continue to be common.

Wherever properly reclaimed swamp lands are found their fertility is recognized; almost without exception they are more fertile than surrounding uplands. They are frequently used in special crop production, such as in growing celery, asparagus, cranberries, or onions, but in dairying or general farming they are unexcelled as permanent pasture or hay land. The consensus of opinion in districts where swamps have been reclaimed and farmed for many years is that there is no more valuable portion of the farm than the swamp, properly reclaimed.

There is much swamp land in the United States within easy reach of the best markets. New Orleans is surrounded by swamps, but here the problem of reclamation is rendered exceedingly difficult owing to the vast area involved and the periodic invasion by the Mississippi River in front, and Lakes Borgne and Pontchartrain in the rear. The city of New York is in the immediate neighborhood of vast areas of swamps and marshes, and even the partial drainage of this land is being productive of admirable results. The great value of stable land in the vicinity of New York for manufacturing purposes is uncontested, and even the partial drainage of the breeding places of salt-marsh mosquitoes in portions of New Jersey adjacent to New York has resulted, aside from limiting the mosquito supply, in the increase in value of the lands to the owners. After the first ditching the crop of salt hay nearly doubles. The operations carried on conjointly between the city of Brooklyn and the town of Sheepshead Bay, a few years ago, showed the remunerative results to be obtained by simple and beneficial operations. The contents of the ash barrels of the city of Brooklyn were conveyed out into the salt marshes upon specially constructed trolley tracks and in large metal tanks. The tanks were so made that upon reaching the terminus they were taken up by machinery, carried out by an overhead trolley line, and by machinery dumped at a given spot. In this way some hundreds of acres of salt marsh were covered with a 12-foot layer of the contents of the ash barrels of Brooklyn. The layer was packed down by water and contained so much organic matter that almost immediately grass and sunflowers began to grow. At the end of the second year enough soil had formed so that Italians had begun to plant cabbages and other vegetables.

The Government is taking up the subject of reclamation of swamp lands through its Reclamation Service, and extensive surveys are being made by the United States Geological Survey. Under the United States Department of Agriculture appropriations have been made for some years to enable the Secretary of Agriculture to investigate and report upon the drainage of swamps and other wet lands and to prepare plans for the removal of surplus waters by drainage.

A number of interesting and important publications have already been issued by the United States Department of Agriculture, two of which are of general interest, namely, Circular No. 74, Office of Experiment Stations, Excavating Machinery Used for Digging

Ditches and Building Levees, by J. O. Wright (pp. 40, figs. 16); and Circular No. 76, Office of Experiment Stations, The Swamp and Overflowed Lands of the United States, by J. O. Wright (pp. 23, pl. 1). The first of these publications described the use and construction of different classes of dredges, including dipper, clam-shell, rotary, roller, scraper, elevator, and hydraulic dredges, and drag boats; first cost and cost of operation of dredges; machines for building levees; machine for tile ditching. The second gives an estimate of the area of swamp lands in the different States, its ownership, present value, cost of reclamation, and probable value when reclaimed, and discusses the state laws relating to drainage. It is shown in the latter circular that there are in the United States 119,972 square miles of swamp lands, an area which, collected together, would be as large as England, Ireland, Scotland, and Wales together, or larger than the six New England States, New York, and the northern half of New Jersey. It would make a strip 133 miles wide reaching from New York to Chicago. Not all of this swamp land, however, is suited for agriculture, but from the data collected by the Office of Experiment Stations of the United States Department of Agriculture, it seems certain that in the eastern portion of the United States there are 77,000,000 acres that can be reclaimed and made fit for cultivation by the building of simple engineering structures. It is a noticeable and significant fact that 95 per cent of this entire area is held in private ownership. The following paragraphs taken from this Circular No. 76 express the desirability of such drainage from the monetary point of view in very forcible terms:

There is no question as to the fertility of swamp or overflowed land, and when it is protected by embankments to keep out the overflow and is relieved of the excess of water by proper drainage its productiveness is unexcelled. In nearly every one of the States large areas of similar lands have been reclaimed by draining and embanking and have proven to be the most productive farm lands in the districts in which they are located. Illinois, Indiana, Iowa, and southern Louisiana have taken the lead in work of this kind, and in no other part of the country do we find more profitable or higher-priced farms than in those States. Along the Atlantic coast sufficient work has been done to indicate that the vast extent of salt marsh reaching from Maine to Florida can by proper methods be won to agriculture, and when reclaimed the soils are especially adapted to market gardening.

To ascertain why these lands have been allowed to remain so long in their present state we must look to some cause other than their lack of fertility, as this has been fully established by chemical analyses of the soil and by hundreds of productive farms that have been made from such lands.

In the early settlement of our country the farms were located on what were considered the most desirable tracts, determined by accessibility, natural water supply, and the fertility of the soil. As civilization extended westward the home seeker selected the rolling prairie that needed little or no drainage, so that the swamps and overflowed lands were passed by, and only recently has an imperative demand arisen for their reclamation. The desirable farming land is practically all occupied or held for speculation, and to meet the needs of our steadily increasing population it is neces-

sary for this swamp land to be drained and put to proper use. Its nearness to market and its great fertility make it very desirable for small farms.

Can these lands be drained, what will it cost, and how can the work best be done are questions of vital interest to the American people. After considering what has been done to reclaim the marshes of Holland, two-fifths of which lie below the level of the sea, and the difficulties that have been overcome in draining the fens of England, it would be a reflection on the skill and intelligence of the American engineer to proclaim the drainage of our swamp lands impossible. On the contrary, the engineering problems are simple, as most of these lands are several feet above sea level and have natural creeks or bayous that need only to be improved by straightening, widening, and deepening to afford outlets for complete drainage. In case of some of the river bottoms and the salt marsh along the coast it is necessary to build levees to prevent overflow and to construct internal systems of drainage with sluice gates or pumps to discharge the water from within, and by the use of modern machinery this work is neither difficult nor expensive. Levees can be built and ditches excavated with suitable dredges at a cost ranging from 7 to 16 cents per cubic yard. Large works in swamps where the land is overflowed are readily and cheaply constructed in this manner.

As to the cost of draining these lands, and whether or not it will pay, we have but to refer to the numerous works of this kind that have been completed. In those States where large areas of swamp land have been thoroughly drained by open ditches and tile drains the cost ranges from $6 to $20 per acre, while in places where tile drainage was not required the average cost has not exceeded $4 per acre. Judging from the prices which prevail in a large number of these districts where work of this kind is being carried on, it is safe to estimate that the 77,000,000 acres of swamp can be thoroughly drained and made fit for cultivation at an average cost of $15 per acre. The market value of these lands in their present shape ranges from $2 to $20 per acre, depending upon the location and prospect of immediate drainage, with an average of probably $8 per acre. Similar lands in different sections of the country that have been drained sell readily at $60 to $100 per acre at the completion of the work, and in many instances, when situated near large cities, they have sold as high as $400 per acre. To determine whether or not it will pay to drain these lands we have but to consider the following figures:

Cash value of 77,000,000 acres after thorough drainage, at $60 per acre.		$4,620,000,000
Present value of this land, at $8 per acre	$616,000,000	
Cost of drainage, at $15 per acre	1,155,000,000	
Value of land and cost of draining		1,771,000,000
Net increase in value		2,849,000,000

These figures, though large, are not fanciful, but are based on results obtained in actual practice in different sections of the country where work of this kind has been done. An extended investigation shows that in every case where a complete system of drainage has been planned and carried out the land has increased in value many fold. In some instances, however, much time and money have been wasted because the work was undertaken without any well-defined plan or it was not sufficient to afford adequate and complete drainage.

The reclamation of swamp and overflowed lands is no longer an experiment; it has become a highly profitable business when based on correct principles. The methods of drainage practiced in different parts of this country and in some of the foreign countries are being carefully considered, and many experiments are being made to determine the best and most economical methods of draining land, and the information thus collected is being classified and the results compared and general rules deduced which, if followed, will in all cases bring highly beneficial results. The comparative cost of the different methods of doing the work and the most satisfactory way of providing funds are also being duly considered.

Were this 77,000,000 acres of swamp and overflowed land drained and made healthful and fit for agriculture and divided into farms of 40 acres each, it would provide homes for 1,925,000 families. Swamp lands, when drained, are extremely fertile, requiring but little commercial fertilizer, and yield abundant crops. They are adapted to a wide range of products and in most instances are convenient to good markets. While an income of $15 to $20 per acre in the grain-producing States of the Middle West is considered profitable, much of the swamp land in the East and South would, if cultivated in cabbage, onions, celery, tomatoes, and other vegetables, yield a net income of more than $100 per acre.

In addition to the immediate benefits that accrue from the increased productiveness of these lands, a greater and more lasting benefit would follow their reclamation. The taxable value of the Commonwealth would be permanently increased, and healthfulness of the community would be improved, mosquitoes and malaria would be banished, and the construction of good roads made possible. Factories, churches, and schools would open up, and instead of active young farmers from the Mississippi Valley emigrating to Canada to seek cheap lands they could find better homes within our own borders.

Holland, two-fifths of which lies below the level of the sea, has been reclaimed by diking and draining, and now supports a population of 450 per square mile. Her soil is no better than the marshes of this country, and her climate not so good as that of the Southern States, yet we have within our border an undeveloped empire ten times her area.

There is no good reason why this condition should longer continue, and it is to be hoped that the American people will soon take steps to abate this nuisance and make these lands contribute to the support and upbuilding of the nation.

In an important article by Mr. H. C. Weeks, in the Scientific American Supplement for January 5, 1901, on the subject of drainage work, the following interesting statements are made:

Cases exist, however, of persons being unwilling to be convinced, and continuing their opposition even after a successful reclamation, as are seen in the official records of Massachusetts, while examinations by the State have shown a great improvement in the sanitary and agricultural conditions. In the instance of Green Harbor, in that State, it is shown that the death rate of the reclaimed district averages lower than the general death rate of the State; that there is a steady increase in summer visitors, and that many houses are being built. The testimony of persons of wide knowledge and ample experience in the science and art of agriculture is adduced, showing the good results in that field, and yet it fails to silence opposers. Besides mentioning the remarkably heavy crops of hay, much preferred by his horses to the best from the uplands, also the excellent crops of strawberries and vegetables raised in these lands, one such qualified observer gives his experience as to asparagus in such convincing words that they are quoted in full: "While visiting the Marshfield Meadows on April 19, 1897, I found asparagus already up, very nearly high enough to cut. I was surprised at this, for my own asparagus had but just appeared above the surface of the ground, although growing on land so warm that I am usually first to ship native asparagus to Boston market. I was also surprised at the size of the stalks, they being much larger than the first set of stalks that appear on my land. When I consider the fact that the land on which this asparagus was growing has produced large crops every year for twenty years without fertilizers of any kind, and still produces better crops than my land, which has had $600 worth of fertilizers to the acre applied to it during the last twenty years, it convinces me that this land, for garden purposes, surpasses any which I have ever examined * * *."

We realize, in a measure, the great value of the material which nature has for ages been storing up for man's future use, if he be wise enough to avail himself of it.

The drainage work done by other countries has given many practical examples of beneficial results from the mosquito standpoint, and from other points of view as well. The details have very recently become available, through the kindness of the United States consul at Milan, Italy, of very extensive drainage operations carried on near Milan, which involved the reclamation of nearly 80,000 acres of land. These details may be found in the Scientific American Supplement No. 1637, May 18, 1907, pages 26233 to 26235. The work cost $3,200,000, and the annual cost of operation is estimated at $16,000. The beneficial results are summarized as follows:

1. In both Mantua and Reggio this tract, comprising 77,867 acres, cultivable only for a sparse crop of poor hay and, on account of the vapors arising from its stagnant swamps, dangerous for pasturage during practically all the year, has been made cultivable, in one year, for wheat, grapes, fruits, and hay, and rendered good for cutting into farms on which people can erect homes in safety.

2. The market values, not only on the 78,000-acre tract but on all contiguous territory, even to the outer bounds of the affected provinces, have leaped to figures equal to two or three times those prevailing before the opening of the Bonifica, i. e., from $120 to $250 or $300 per acre.

3. Farm labor, which formerly expressly avoided these provinces, and made difficult the harvesting of the extensive crops, has been attracted there by the changed conditions; while on account of the demand created by the active development of the drained tract, wages have not been knocked down by the plentitude of supply.

4. Live-stock maladies are under better control.

5. The public health has been afforded a sure and scientific protection.

SALT-MARSH LANDS IN NEW JERSEY.

So much work has already been done in New Jersey that, as repeatedly pointed out in this work, the value of the operations already carried on in that State is very great, if only as an indication of what can be and should be done elsewhere. The whole question of the New Jersey salt marsh and its improvement has been considered by Dr. John B. Smith in Bulletin No. 207 of the New Jersey Agricultural Experiment Station. In this work he gives a consideration of the location of the salt-marsh area, the kinds of salt marsh, the vegetation on the marshes, the present value of the marshes, their actual value, effect of drainage on crops, the needs of salt grass and black grass, and a general consideration as to how the marshes may be reclaimed and who is to pay the expense.

It appears that the present value of the marshes is very small. As a matter of fact, they are either not taxed at all or at such a low rate as to add little to the income of the taxing body. Some of the owners have never paid any taxes, and in some of the townships there is no record of ownerships in the assessor's hands and therefore no notices can be served. It is pointed out, as an evidence of the recognized worthlessness of such land, that none who work on them consider in the least the results of interference with natural

drainage; railroads build embankments across them, and pay no attention to the water courses except large creeks. The result is that the marsh often becomes water-logged, and a good salt-hay meadow is turned into a quagmire, and not even the owner protests. Railroads cut sods from the meadows without inquiry as to the ownership of the land, and holes of all sizes are scattered over the meadow, most of them unconnected with tidewater, leaving stagnant pools in which mosquitoes breed.

He points out that all salt marsh, of what he names the third type, which is that area above mean high tide and more or less completely covered with vegetation, may be made to produce an income of from $10 to $40 per acre annually, and that there are many hundreds of acres that do produce such incomes.

In considering the effect of drainage upon crops he gives a number of interesting instances, three of which are quoted:

The Newark meadow has an area of about 3,500 acres, and hay has been cut on parts of it for many years. Before the 90's it was generally cut by men who wished to use it as food for stock or as bedding, and some ditches were cut by those who noticed that well-drained land produced much better crops than such as were either too dry or water-logged. After the 90's a number of banana houses opened in Newark and created a demand for salt hay to use in layering the ripening fruit. This demand led to the cutting of more territory around the edges of the marsh, and $5 a ton was paid for the crop. With the introduction and increase of the glass industry the demand for hay, to be used as packing, increased steadily, and yet greater areas were cut; and in order to get at these areas the cutting was done in the winter, after the meadow was frozen solid, for at no other time could the product be carted off. And this was the condition of affairs in 1904, when the mosquito drainage was done by the city, but under the supervision of the writer. It might be said here that this drainage work was not looked upon with any favor by owners and haymakers, the latter especially protesting vigorously. One man threatened to smash the ditching machine, and yet another promised to shoot the first man that set a spade into his property. The work went on, nevertheless, and altogether nearly 400,000 feet of ditches went into this 3,500 acres.

The results are as follows: On the Hamburg section, where in 1903, on an area nearly one mile square, about 100 tons of hay were taken off during the winter, 250 tons were carted off in 1904, only one year later. The meadow has hardened up right along, and in 1907 nearly the entire area was cut by machine, and a crop of 800 tons, valued at $7.50 per ton, is harvested. Yet a worse place was the area, about one by three-fourths of a mile, known as the Ebeling tract, little more than a sunken meadow before 1904, from which no more than 30 tons of usable grass were obtained. After the ditching the meadow began to rise and improve, and at present writing is at least seven inches above its 1903 level, and correspondingly improved in texture. The crop has increased from 30 tons to 600 tons, not quite so good as the other, but worth an average of $7 per ton. Other areas which had theretofore produced nothing are now being cut. The total cut in 1903 was between 1,000 and 1,200 tons; the 1907 crop will come close to 3,000. And that is not the limit of productiveness.

Forty years ago the Elizabeth marshes, containing about 2,200 acres, were quite generally cut over and good crops of hay were obtained. There was considerable ditching done, but it was not kept up, and as the marsh was crossed and cut up by the railroads without regard to the drainage system, matters became gradually worse; the meadow rotted, the black and salt grass was replaced by sedges and other useless stuff, and less and less was cut each year until, for a decade past, little or nothing has been

cut from the area west of the Central Railroad. Where as much as 5,000 tons had once been harvested, less than a thousand tons were harvested in 1903. In 1906 ditches were cut in the southeastern section of the meadow in the course of the mosquito work, and an area on which hip boots were needed in that year can now be safely traveled dry shod. Where we found sedge and useless grasses over two-thirds of the area in 1905, on that same proportion we now have good salt and black grass. In another year, if the ditches are not interfered with, the sedge will be practically out. The balance of the area was ditched early in 1907, all the work being completed early in July. Shallow depressions that have been water covered and mosquito breeders for twenty years are now dry and covered with the salt-marsh flea-bane. The grass which was ten to twelve inches high last year is now twenty to twenty-eight inches high and much more dense. For the first time in nearly twenty years hay is being again cut in areas west of the railroad and in the area between Great Island, Elizabethport and the Central Railroad.

In draining the Shrewsbury River marshes in 1904, the same sort of opposition from hay producers was encountered that we met on the Newark marshes, and it was objected that the ditches cut up the land and made work harder. Nevertheless, the work was done and the result is a crop just double—mostly from longer, thicker grass. Before 1904, two tons per acre was considered a good crop; now, good and bad together, it averages four tons, and local conditions furnish a market that pays $10 per ton.

In his annual report for the year 1908, Doctor Smith states that his investigations showed that a very small part of the salt-marsh area produces as great a crop as it should, and that what is produced does not bring as good a price as it should. The market for salt hay is slight, due in part to the character of the crop and partly to the uses to which it is put. Since the crop is not certain it can not be relied upon, and the price varies with the size of the harvest. Salt hay is used largely for packing, and the amount demanded depends upon business conditions. In 1907 there was a very large crop of hay, but there was a business depression at the same time which brought about so low a price as to scarcely repay harvesting. He shows that salt hay is altogether too valuable to be used for packing material alone, and that if an annual crop could be expected it could be used to supplement upland hay in feeding horses and cattle. The drainage work done by Doctor Smith under the state mosquito law will put the meadows into such shape that the amount of hay produced will be increased without increase of cost except in harvesting, and will enable the production of dependable crops. He states that on July 21, 1908, he had the opportunity of seeing, at Stratford, Conn., an area of about 1,500 acres of salt marsh drained and partly diked and reclaimed. The largest part of the acreage was devoted to raising salt hay of the best quality, for which good prices were received. On the diked marsh 100 acres had been kept free from salt water since 1904. On this territory strawberries, asparagus, onions, and celery were being raised, and, while the asparagus was not of the best quality and the strawberry plants were in no way unusual, the onions and celery were of the best—in fact the celery was so good that most of

the market gardeners in that vicinity preferred to get their supplies from this source.

Doctor Smith points out that there are many hundreds of acres along the shores of Barnegat Bay, and especially along its upper portion, where a very small amount of diking will serve to keep out salt water and fit the land for certain truck crops. He also shows that along a large portion of the Barnegat Bay line cranberry plants grow annually to the very edge of the salt-marsh line, but that these could not be improved because there was no way out across the marsh for surface water. With the ditching going on, this land will become available in large part at least and will allow the owners to derive a revenue from land which is at present practically nonproductive. Of course taxes will then be raised and the income of the townships in which this land lies will be increased.

THE PRACTICAL USE OF NATURAL ENEMIES OF MOSQUITOES.

SALAMANDERS, DRAGONFLIES, PREDACEOUS MOSQUITOES, AND FISH.

Almost no practical use has been made artificially of the natural enemies of mosquitoes except with fish. It is true that about 1898 Mr. Albert Koebele imported from California into Hawaii a large number of western salamanders (*Diemyctylus tortosus* Esch.), which were liberated in the upper part of the Makiki stream in the hope of reducing the large number of mosquitoes breeding in small pools and in the taro fields. He kept two of these salamanders for several weeks in an open tank and they devoured all mosquito larvæ that occurred there; and while hundreds of the newly hatched mosquito larvæ could always be observed, none of them ever reached full growth. Whether these salamanders have increased in Hawaii and at present form an important element in the mosquito environment is not recorded.

Among the predatory insects it has been frequently suggested that dragonflies are such important mosquito enemies that efforts should be made to devise some artificial means of encouraging their increase, and in fact the late Dr. R. H. Lamborn, of New York and Philadelphia, offered a series of prizes for the three best essays regarding the methods of destroying mosquitoes and house flies, especially designating the dragonfly for careful investigation. The prizes were awarded to Mrs. Carrie B. Aaron, of Philadelphia, and Mr. A. C. Weeks and Mr. Wm. Beutenmueller, both of New York, but none of the essayists was able to solve the problem of the practical breeding on a large scale of dragonflies for mosquito extermination.

It has been proposed to breed mosquitoes of the genera Psorophora and Megarhinus, the larvæ of which are extremely active and feed so voraciously upon the larvæ of other mosquitoes, but Psorophora

itself in the adult condition is a voracious biter and is a potential carrier of disease, so that to breed it for predaceous purposes is hardly to be considered; in other words, the remedy might prove worse than the disease. However, Dr. Oswaldo Goncalves Cruz, director-general of the board of health in Rio de Janeiro, told the writer in November, 1907, while on a visit to Washington, that *Lutzia bigotii* is used in Rio practically to destroy the larvæ of the yellow-fever mosquito. The Lutzia larvæ are exclusively carnivorous, and this species is introduced in regions where the mosquito abounds, and its larvæ destroy the other larvæ as efficaciously as do fish.

For a long time fish have been used practically on a small scale. For example, it was stated a number of years ago in Insect Life that mosquitoes were at one time very abundant on the Riviera in south Europe, and that one of the English residents found that they bred abundantly in water tanks, and introduced carp into the tanks for the purpose of destroying the larvæ. It is said that this was done with success, but it is rather certain that the fish must have been some other form than carp. It is probable that the fish in question was the common goldfish (*Carassius auratus*).

In the southern United States for many years intelligent persons here and there have introduced fish into water tanks for this purpose. Mr. E. A. Schwarz found in 1895 that at Beeville, Tex., a little fish was used. The fish was called a perch, but its exact specific character is not known. Prior to 1900, Mr. F. W. Urich, of Trinidad, wrote the Bureau of Entomology that there is a little cyprinoid, common in that island, which answers admirably for the purpose. In a letter to the Bureau of Entomology Mr. J. B. Fort, of Athens, Ga., writes that about 1854 his father, Dr. Tomlinson Fort, living at Milledgeville, Ga., found that mosquitoes were breeding extensively in a cistern owned by certain livery-stable keepers. They refused to use oil upon their cistern, and Mr. Fort was instructed by his father to catch some small fish from a creek near by and place them in the cistern. About a dozen or more small fish were so placed, and in a day or so all of the larvæ were destroyed. This instance is mentioned as indicating the early use of fish on a small scale in cisterns.

In "Mosquitoes" (1901) the writer recommended the practical use of sticklebacks, top-minnows (*Gambusia affinis* and *Fundulus notatus*), and the common sunfish or pumpkinseed, and these fish, especially the top-minnows and the sunfish, were used with success in a number of instances in small ponds. An instance has been described in a letter to the Bureau of Entomology by C. T. Anderson, of Anderson, Washington County, Fla., who wrote that he had a spring on his place that swarmed with mosquito larvæ in the summertime. He got about a dozen top-minnows and put them into the spring without

telling the rest of the family. In a day or two a member of the family remarked that there were no wrigglers in the water. Mr. Anderson verified the observation, and after many months was able to state that no mosquito larvæ had been seen since.

The common goldfish proves to be an excellent mosquito feeder and during the summer of 1901 Mr. Jacob Kotinsky, then of the Bureau of Entomology, conducted a series of laboratory experiments with goldfish in an aquarium. He found that they were voracious feeders on mosquito eggs, preferring them to larvæ. He further noticed that the fish, after taking several larvæ into the mouth, would eject some of them. Further, he found that in a large jar containing four goldfish and many hundreds of mosquito larvæ, a few of the larvæ succeeded in transforming and emerging as adult mosquitoes. The food supply was evidently in excess of the capacity of the fish.

At an earlier date than this Mr. H. W. Henshaw, of the Biological Survey of the United States Department of Agriculture, was staying at Fruitville, near Oakland, Cal. The house and neighboring houses were badly infested with mosquitoes. He found the source of supply to be a lily pond about 7 by 12 feet in size and fully 3 feet deep, which was fairly swarming with larvæ. He got a half dozen goldfish from San Francisco and put them into the pond. The following day they were so badly bloated that they could hardly swim, and in a few days there was not a single larva left. The fish bred in the pond and from the time of their introduction there was a very marked decrease in the number of mosquitoes in that general locality.

Mr. William Lyman Underwood, of the Massachusetts Institute of Technology, in Science for December 27, 1901, described an interesting experience with goldfish:

About six years ago, at my home in Belmont, near Boston, Mass., I constructed a small artificial pond in which to grow water lilies and other aquatic plants and also to breed, if possible, some varieties of goldfish—though the latter object was a secondary consideration. The advisability of making this pond had been somewhat questioned on account of its close proximity to my house and the fact that such ponds are likely to become excellent places for the propagation of mosquitoes. Nevertheless, the plan was carried out and the pond was stocked with goldfish taken from natural ponds in the vicinity where they had been living and breeding, to my personal knowledge, for a number of years.

The aquatic garden has proved a success and the goldfish have meantime thriven and multiplied. Moreover, no mosquitoes attributable to the pond have appeared and I have been unable to find any larvæ in it, although I have searched repeatedly and diligently for them. I have always believed that the absence of mosquito larvæ from this pond was due to the presence of the goldfish, and I have so stated in a paper, "On the Drainage, Reclamation, and Sanitary Improvement of Certain Marsh Lands in the Vicinity of Boston" in the Technology Quarterly, XIV, 69 (March, 1901), as follows: "In the water (of this pond) are hundreds of goldfish that feed upon the larvæ of mosquitoes and serve to keep this insect pest in check." * * * I took from the pond a small goldfish about three inches long and placed it in an aquarium where it could, if it would, feed upon mosquito larvæ and still be under careful observation. The result was as I had anticipated. On the first day, owing perhaps to the

change of environment, and to being rather easily disturbed in its new quarters, this goldfish ate eleven larvæ only in three hours; but the next day twenty were devoured in one hour; and as the fish became more at home the "wrigglers" disappeared in short order whenever they were dropped into the water. On one occasion twenty were eaten in one minute, and forty-eight within five minutes. This experiment was frequently repeated, and to see if this partiality for insect food was a characteristic of those goldfish only which were indigenous to this locality I experimented with some said to have been reared in carp ponds near Baltimore, Maryland. The result was the same, though the appetite for mosquitoes was even more marked with the Baltimore fish than with the others. This was probably due to the fact that they had been in an aquarium for a long time before I secured them, and had been deprived of this natural food. I also tried the experiment of feeding commercially prepared "goldfish food" and mosquito larvæ at the same time, and found that in such a case the goldfish invariably preferred the larvæ.

It is not as generally realized as it should be that goldfish will thrive in our natural northern waters. In my experience they can easily be bred in any sheltered pond where the water is warm and not fed by too many cold springs, and for many years they have been breeding naturally in many small ponds in the vicinity of Cambridge, Massachusetts.

When it is once understood that these fish are useful and ornamental, as well as comparatively hardy, it is to be hoped that they will be introduced into many small bodies of water where mosquitoes are likely to breed, and thus be employed as a remedy for mosquitoes sometimes preferable to kerosene.

The year 1908 in the island of Cyprus proved to be the most malarious year since 1885. Careful examination of conditions was made by Dr. George A. Williamson, whose report will be found in the Journal of Tropical Medicine and Hygiene, September 15, 1909, pages 271–272. A careful search was made in the marshes to the north and south of Larnaca, but no breeding places of Anopheles mosquitoes were found, and subsequent search showed that the malarial mosquitoes were breeding in the tanks and wells of private houses. Here kerosene could not be used, and the use of goldfish was advised. Wherever the advice was followed the results were perfect. One well, described by Williamson, was about 20 feet deep and had a wide mouth. This well contained Anopheles larvæ in enormous numbers, and of five persons living within its immediate neighborhood four became infected with malaria. This well, not being in use, was filled in, but a large tank which was near it was stocked with goldfish and all Anopheles larvæ were destroyed by them.

An excellent discussion of the relative value of the different small fish for practical handling and for practical use against mosquito larvæ has been published by Mr. William P. Seal, a naturalist of many years' experience in handling fishes, and the following paragraphs taken from this article[a] may be considered as authoritative:

As a destroyer of Anopheles the writer has for several years advocated the use of *Gambusia affinis*, a small viviparous species of fish to be found on the South Atlantic coast from Delaware to Florida. A still smaller species of another genus, *Heterandria*

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[a] See Scientific American Supplement, vol. 65, No. 1691, pp. 351–352, May 30, 1908.

formosa, is generally to be found with Gambusia and is of the same general character. The females are about one inch long and the males three-quarters of an inch. Both of these species are known as top minnows, from their habit of being constantly at the surface and feeding there. The conformation of mouth, the lower jaw projecting, is evidence of their top-feeding habits. Both of these species are to be found in great numbers in the South in the shallow margins of lakes, ponds, and streams in the tide-water regions wherever there is marginal grass or aquatic and semiaquatic vegetation. They are also to be found in shallow ditches and surface drains where the water is not foul, even where it is but the fraction of an inch deep. In fact, if any fishes will find their way to the remotest possible breeding places of the mosquito, it will be these. And they are the only ones, so far as the writer's observation goes, that can be considered useful as destroyers of Anopheles larvæ.

Gambusia is found in the Ohio Valley as far north as southern Illinois, where the winter climate must be at least as severe as that of the coast of New York and New Jersey.

Dr. Hugh M. Smith, Deputy U. S. Fish Commissioner, informed the writer that he had examined the stomachs of several hundreds of Gambusia in the Chesapeake Bay and Albemarle Sound waters, and had found the contents to be principally mosquito larvæ. * * *

While, as has been stated, all fishes have some measure of usefulness, if only in the way of deterrent effect, there are only a few species likely to be found in waters in which mosquitoes breed. The most important of these are the gold fish (introduced), several species of Fundulus (the killifishes), and allied genera, three or four species of sunfish, and the roach or shiner, and perhaps one or two other small cyprinoids. In addition, there are a few sluggish and solitary species, like the mud minnow (Umbra) and the pirate perch (Aphredoderus). The sticklebacks have been mentioned in this connection, but the Atlantic coast species, and probably the entire family, are undoubtedly useless for the purpose, being bottom feeders, living in the shallow tide pools and gutters, hidden among plants or under logs and sticks at the bottom, where they find an abundance of other food.

In the salt marshes there are myriads of killifishes running in and out and over them with each tide, while countless numbers of other and smaller genera, such as Cyprinodon and Lucania, remain here at all stages of the tide. So numerous and active are all of these, that there is no possibility of the development of a mosquito where they have access.

Of the killifishes two species, Heteroditus and Diaphanous, ascend to the farthest reaches of tide flow, but it is a question as to whether they would prove desirable for the purpose of stocking land-locked waters, since they are a good deal like the English sparrow, aggressive toward the more peaceable and desirable kinds. Even Cyprinodon, which would at first thought be a valuable small species in this respect, is viciously aggressive toward goldfish and no doubt all other cyprinoids. It is so characteristic of all the cyprinodonts, that they can only be kept by themselves in aquaria. They are the wolves or jackals of the smaller species.

The writer has come to the conclusion, after many experiments in both tanks and ponds, that a combination of the goldfish, roach, and top-minnow would probably prove to be more generally effective in preventing mosquito breeding than any other. The goldfish is somewhat lethargic in habit, and is also omnivorous, but there is no doubt that it will devour any mosquito larvæ that may come in its way or that may attract its attention. The one great objection is that they grow too large, and the larger will eat the smaller of them. That is one of the drawbacks to goldfish breeding. There is no danger of overpopulation, but there is of the reverse. Whether or not it is the same with the roach, they are never excessively numerous, although no doubt the most abundant and most widely distributed of the Cyprinidæ. They are largely the prey of predaceous fishes, and never approach to the numbers of the killifishes.

But at all events they are not lethargic like the goldfish, being on the contrary one of the most active of the family, and equally at home in flowing or stagnant water. The roach is always in motion, back and forth, and around and about, on a never-ending patrol.

The top-minnows would supply the deficiencies of the other two species, and in combination they should very thoroughly populate any waters not already stocked with predaceous kinds, and exercise an effective control. One of the great difficulties in the case is that there are dozens of kinds of insect larvæ besides those of the mosquito, and other forms of life as well, which are natural and possibly preferred food of the fishes, thus requiring an enormous population to devour them all.

The larvæ of gnats, midges, ephemera, and other flies and insects which breed in the water, as well as the many small crustaceans, afford a menu of delicacies that would stagger a gourmand. The above combination of mosquito destroyers might be supplemented by two small species of sunfish, *Enneacanthus obesus* and *E. gloriosus*, which live among plants and would be a check on larvæ other than the mosquito. The black-banded sunfish, *Mesogonistius chætodon*, would also be desirable for this purpose if they were not so difficult to obtain in large numbers. One or both species of Enneacanthus can be found wherever there are aquatic plants. The above-mentioned five species in combination seem to be the most suitable for pond protection of all those which are known to thrive in still water and which in any degree possess the desired qualities. As has been stated, the killifishes would probably be found to be undesirable. In their natural habitat, the tidal streams and great expanses of small marsh, their efficiency is unquestioned.

There are many places at the seashore where there are swales or hollows filled with grasses and bushes, which in periods of rainfall become breeding places for the mosquito, especially of Anopheles. If these places are stocked with fish, the result is that when they dry up the fish perish, and the operation must be repeated after each filling.

The writer has suggested digging holes about four feet square down through the turf into the sand stratum in the deepest part. Two feet is usually sufficient to secure a constant water supply where the fish can exist until the hollow is again rain-filled. Cyprinodon and Lucania would be desirable for such places, and they are to be found everywhere in the ditches and tide pools on the flats.

To add variety to the treatment of the subject, it might not be amiss to suggest that there is a fish, Anablaps, inhabiting the fresh waters of South America, which seems to be specially adapted to this purpose. To quote: "These small fishes swim at the surface of the water, feeding on insects, the eye being divided by a horizontal partition into a lower portion for water use and a portion for seeing in the air."

Acting largely upon Mr. Seal's advice, Dr. John B. Smith, the state entomologist of New Jersey, with Mr. Seal's help, in November, 1905, brought *Gambusia affinis* and *Heterandria formosa* from North Carolina into New Jersey, which were distributed as follows: Eight thousand in spring and natural drainage rivulets flowing into the ice pond at Westville, N. J., 600 in a landlocked pond near Delanco, 600 in a mill pond between Merchantville and Evesboro, 600 in landlocked waters near Delair, and 400 in ponds of the Aquarium Supply Company, at Delair. In Doctor Smith's report for the year 1906 it was stated that the experiment was to be written down a failure. Whether it was due to the destruction of the introduced fish by black bass, pike, yellow perch, and sunfish, or whether because of other enemies, or because of their dislike to their changed conditions, they found their way during

the spring rains to rivulets flowing to the Delaware River, or whether they escaped in other ways, could not be told. In his report for 1907, however, Doctor Smith states that the Gambusia was found in large numbers in Teals Branch of Pond Creek, a small tributary of Delaware Bay at Higsbie's Beach, by Mr. Henry W. Fowler, of the Academy of Natural Sciences, Philadelphia, and Messrs. H. Walker Hand and O. H. Brown. These gentlemen found it also very abundant in New England Creek, another tributary of Delaware Bay just north. Doctor Smith states that Mr. Seal was inclined to claim that this finding was the result of his work in 1908, but that Mr. Fowler doubted this conclusion since the points where found were 90 miles distant from points of introduction.

FISH INTRODUCED INTO HAWAII TO ABATE MOSQUITOES.

In the early part of 1903 Mr. D. L. Van Dine, then entomologist of the Hawaii Agricultural Experiment station of the U. S. Department of Agriculture, brought up the question of introducing top-minnows into Hawaii, since his investigations of the mosquito problem in the islands indicated that no effective natural enemies existed there. Dr. David Starr Jordan, to whom the problem was referred, informed Mr. Van Dine that while these fish had never been transported for such a great distance, they were extremely hardy, and that the experiment would be well worth while. The cost of the experiment, however, was prohibitive at the time, and it was not until 1904, when a Citizens' Mosquito Campaign Committee was organized in Honolulu, that the requisite funds were raised. Mr. Alvin Seale, an assistant of the Bureau of Fisheries, United States Department of Commerce and Labor, was chosen to do the work, and with an advance of $500 started in July, 1905, from Stanford University to the southern United States. He proceeded to Seabrook, near Galveston, Tex., where he found top-minnows in large numbers. They were swarming in all the stagnant waters at sea level, as well as in various ditches, ponds, and standing pools. Mr. Seale found that mosquitoes were very plentiful about Seabrook, but after careful study he convinced himself that they did not breed at all extensively in the bodies of water containing the fish, but in temporary and artificial breeding places, such as closed pools, tubs, and tin cans, not accessible to fish. Doctor Jordan had advised the collection of fish of the following genera: Mollinesia, Adinia, Gambusia, and Fundulus, all members of the family Pœciliidæ, the top-minnows. Mr. Seale made careful examinations of the stomach conditions of the minnows of the genera recommended by Doctor Jordan. These stomach contents were found to consist largely of larvæ of various insects, including those of mosquitoes, of the egg-masses of mosquitoes, of minute crustacea, and of some vegetation. The fish of the genus Gambusia were found to be

the best insect feeders. The temperature of the water ranged from 74° to 87° F. Careful experiments were made with 10-gallon milk cans, in order to determine the conditions under which the fish could be most successfully transported to Hawaii. These experiments included observations on temperature of the water and on changing the water, and from these experiments was ascertained the necessary information in regard to the frequency of changing and the fact that best results could be obtained by transporting them in water of the normal temperature. The three most abundant species, *Gambusia affinis*, *Fundulus grandis*, and *Mollinesia*, were then collected and about 75 were placed in each can, a 20-gallon tin tank full of water being taken along as a supply reservoir. Mr. Seale left Seabrook on September 4, 1905. On the journey the fish were fed sparingly every morning at 8 o'clock on prepared fish food, finely ground liver, or hard-boiled eggs. At half past nine one-half of the water in each can was drawn off from the bottom, thus cleaning the cans and removing uneaten food and excrement. An equal amount of fresh water was added. At noon the cans were aërated by means of a large bicycle pump, a sponge being tied over the end of the hose to separate the air into fine currents. At four in the afternoon 2 gallons of water were drawn off from the bottom and 2 gallons of fresh water put in, and the aëration was repeated just before bedtime. Careful tests of water at each place of changing were made by experimenting with two fish. At El Paso, Tex., there was so much alkali in the new water that the fish were killed; at Los Angeles and at San Francisco the water was good. Twelve fish died between Galveston and San Francisco, and 15 between San Francisco and Honolulu. Honolulu was reached on September 15, 1905, with a loss of 27 out of approximately 450 fish. On arrival the fish were placed in the breeding ponds prepared for them at Moanalua, near Honolulu, where four ponds had been made ready. The fish thrived in all of the ponds almost equally well. They were protected by screens from predatory fish and from being carried out to sea by a freshet. In an official bulletin issued July 25, 1907, Mr. Van Dine reported that the fish had multiplied rapidly and from the few hundred introduced several hundred thousand had been bred and distributed. They had proved very effective against mosquito larvæ and also against mosquito egg-masses. Later advices show that the good work is continuing, and the experiment seems to have been a great success.

FISH IN THE WEST INDIES.

Girardinus pœciloides, a small top-minnow, occurs very abundantly in Barbados, where the popular name "millions" has been applied to them. This fish is very small in size, the grown female measuring about 1½ inches in length, while the male is much smaller. The

female is dull in color, without conspicuous markings, while the male is marked with irregular red splotches on the sides and has a circular dark spot on each side. The fish is a rapid breeder and thrives and multiplies in captivity in water-tanks, reservoirs, and fountains, and garden-tubs in which aquatic plants are kept. They are greatly used in this way both in the towns and on the estates to reduce the annoyance of mosquitoes. In 1905 this fish was introduced by the Imperial Department of Agriculture of the British West Indies from Barbados into St. Kitts, Nevis, and Antigua. In 1906 it was introduced into Jamaica and in 1908 into St. Vincent and St. Lucia, and into Guayaquil in Ecuador. An account of these introductions is given in a pamphlet entitled "Millions and Mosquitoes," by H. A. Ballou, issued in 1908 by the Imperial Department of Agriculture of the West Indies (No. 55). In August, 1905, a number of fish were sent to Antigua in a kerosene tin. They arrived in good condition and were kept in a tank at the botanic station until they had sufficiently increased to be distributed. They were liberated in several ponds and streams and increased so rapidly that the country board of health undertook the work of stocking all the ponds and streams of the island. Three years after the first introduction all of the more or less permanent water of Antigua had been stocked, and Mr. Ballou states that many planters and others have commented on the apparent abatement of the mosquito nuisance in many localities. At St. Kitts the introduction was equally successful, but the local government did not take up the distribution of the fish as in Antigua. In Jamaica they were established with good results. "Millions" may be fed in captivity on mosquito eggs and larvæ, on raw beef or hard-boiled eggs, upon small insects of any kind, and even upon corn meal. They are readily transported short distances in a kerosene tin with no other preparation than a wire netting arranged near the top to prevent the fish from being thrown out if the water is splashed about. These fish have been introduced at the Isthmus of Panama.

FISH IN GERMAN EAST AFRICA.

Mr. J. Vosseler, in an article entitled "Fische als Moskito-Vertilger,"[a] gives an interesting account of some experiments with mosquito-feeding fishes in German East Africa. He discusses the question quite as authoritatively as does Mr. Seal, already quoted, and brings out the point that on account of the great physical and chemical differences in the water inhabited by mosquito larvæ the selection of suitable species of fish is made difficult by several restrictions. He states that the shallow shores of rivers or large lakes can be excluded from consideration, since the young of most species of fish

[a] Published in Der Pflanzer. Ratgeber für Tropische Landwirtschaft, for June 13, 1908, vol. 4, No. 8, pp. 118–127.

living there frequent the shores in shoals and prey upon the various forms of animal life, mosquito larvæ included. Many water supplies, however, contain salt and other chemicals, and are polluted from various sources, even from the excrement of game coming to drink; while temporary collections, such as pools, puddles, and irrigation ditches, contain turbulent, muddy water. The level of the water in these different conditions is very variable, and the temperature of the water goes through great variations within a single day, often in midday the heat rising above the limit which most fishes can stand. A fish which would withstand all these conditions would be very exceptional. While we are considering the question of fish introduction, the adaptability of the species to acclimatization, its power of enduring long transportation, and its ability to multiply rapidly, even under adverse conditions, are of vital importance to success. In his travels through the land of Oram (Algeria) in 1892, Mr. Vosseler found a widely distributed species occurring in thousands not only in the springs of salt or magnesia water as well as in the irrigation ditches, but also in the highly polluted, badly smelling pools used to water camels, in which 300 to 400 camels often waded in one day. He found the same species afterwards in pure fresh water, in hot springs, and in brackish water. He also found that it inhabits the subterranean waters of the desert and is probably brought up by boring for artesian wells. One of the officers of the garrison situated in the midst of a salt basin without outlet pointed out to Mr. Vosseler that this little fish eats mosquito larvæ, which explained the comparative absence of mosquitoes in that locality. Mr. Vosseler attempted the introduction of these fish into Germany and succeeded very well in spite of inadequate preparation. They began to lay eggs within a week of their arrival, and have become accustomed to proper food. They always prefer mosquito larvæ and small crustaceans. The fish in question is *Cyprinodon calaritanus*. The female is 8 centimeters and the male 5 centimeters long. The eggs are attached singly to water plants or stones at the rate of one or two a day. Mr. Vosseler states that the excellent qualifications of the species are shared by other members of the same family. In German East Africa at least 2 genera and 5 species are known.

A BRAZILIAN FISH.

Excellently practical results are reached in Rio de Janeiro by the use of a small fish known as the "barrigudo" (*Girardinus caudimaculatus*) which, in the great prophylactic work carried on in that city under the public-health service, is placed in tanks and boxes where it is impossible to use petroleum, and devours the larvæ of mosquitoes most voraciously.

MR. THIBAULT'S OBSERVATIONS.

In considering the normal relation between mosquitoes and fish, Mr. James K. Thibault, jr., of Scott, Ark., in a recent communication presents some interesting views and gives an interesting instance which he considers typical in some localities:

Personally, I do not think that mosquitoes ever breed in the presence of fish if the water is open, allowing the fish free access to the larvæ, yet it is a matter of common observation that under certain favorable circumstances some species do breed regularly in streams where fish are abundant. Yet even where conditions are favorable only a very few species seem to take advantage of it. So far as my own observations go the only mosquitoes that regularly do so in this locality are *Anopheles quadrimaculatus* and *Culex abominator*.

Conditions are favorable when the surface of the water becomes carpeted with aquatic vegetation which restrains the fish in their movements yet allows ample room and protection for the larvæ of the above-named species. There is a certain deep, slowly running bayou here that is the main breeding place for *quadrimaculatus* and *abominator* at present, while two years ago not a larva could be found there at all. The explanation is simple and may be given as a typical example of its kind. Two years ago launches passed through this bayou daily and all logs and drift were removed as soon as found so that the water had free passage and the pondweeds found no foothold, except very near the banks where they were completely destroyed by stock. After the launches stopped passing through this bayou logs soon accumulated and the pondweeds immediately took possession, so that throughout the present season *quadrimaculatus* and *abominator* have bred continuously and abundantly in this bayou.

It must be noted in passing that the larvæ, pupæ, and freshly emerged adults bred in such a location are invariably bright grassy green in color, which gives them an additional advantage over the fishes. This is not the case with larvæ, etc., found in other places.

DESTRUCTION OF LARVÆ.

Of course the abolition of accidental breeding places, the undertaking of drainage measures, and the practical use of natural enemies such as fish, result in the destruction of larvæ, but in this section it is proposed to treat of those measures which involve the use of what have come during recent years to be termed "larvicides." The dictionary definition of the word insecticide is "one who or that which kills insects, as insect powder;" therefore a definition of larvicide would be one who or that which kills larvæ. But in mosquito work it has come to be used for those substances which are applied to bodies of water in which mosquito larvæ are living, and which result in their destruction in one way or another. These substances, for the most part, are either poisons or more frequently oils which, forming a surface film, destroy the larvæ when they come to the surface to breathe. Ronald Ross long ago pointed out the great desideratum in this direction in the following words:

I have long wished to find an ideal poison for mosquito larvæ. It should be some solid substance or powder which is cheap, which dissolves very slowly, and which when in weak solution destroys larvæ without being capable of injuring higher ani-

mals. What a boon it would be if we could keep the surface of a whole pond free from larvæ simply by scattering a cheap powder over it, once in six months or so. It is very possible that such a substance exists, but unfortunately we have not yet discovered it.[a]

A great many experiments have been tried with poisonous substances in the search for the desideratum described by Doctor Ross, but although it is now seven years since he wrote this paragraph we still have failed to discover it. As early as 1899 Celli and Casagrandi published an account of an elaborate series of laboratory experiments on the destruction of mosquitoes by various chemicals in a paper entitled "La Distruzione delli Zanzare," published in the Annali d'Igiene Sperimentale. These experiments resulted in little practical good, and practically the best of all the larvicides, namely, the petroleum products, were discredited by the authors in question.

In the last few years many substances have been experimented with, both in the United States and in other parts of the world, and there has been from time to time a newspaper notice, or a series of newspaper notices, of some new substance which careful experimentation has shown to be of little or no service. In this way the use of permanganate of potash received much advertising in 1900, but as the writer has elsewhere pointed out, as a result of careful experimentation it was found that small amounts of the chemical have no effect whatever upon mosquito larvæ, which were, however, killed by using amounts so large that instead of using a handful to a 10-acre swamp, as had been stated in the newspapers, at least a wagon load would have to be used to accomplish any result; moreover, twenty-four hours after the use of this large amount and after the larvæ were killed, the same water sustained freshly-hatched mosquito larvæ perfectly, so that even were a person to go to the prohibitive expense of killing mosquito larvæ in the swamp with permanganate of potash the same task would have to be done over again two days later.

In 1904 a publication by the Bureau of Plant Industry of the United States Department of Agriculture, on the use of sulphate of copper against algæ and other microscopic plant-life, put certain newspaper men on the wrong track, and a number of articles were published making the erroneous statement that the Department of Agriculture recommended sulphate of copper as a perfect remedy against mosquito larvæ. So widely was this alleged discovery heralded that careful experiments were at once made in the Bureau of Entomology, by Dr. John B. Smith, of New Jersey, by Dr. W. E. Britton, of Connecticut, and by other entomologists, with the result that the substance was found to be of very slight value as a larvicide, and of really no practical value whatever.

Several proprietary mixtures or mosquito compounds have been prepared and placed on sale for the purpose of destroying mosquito

[a] Mosquito Brigades, London, 1902, pp. 33–34.

larvæ. A number of these have been brought or sent to the writer for experimentation, but, considering the cost, none of them has been of as great practical value as petroleum. In his report on the mosquitoes occurring in the State of New Jersey,[a] Dr. John B. Smith describes a number of experiments with substances of this kind, notably with certain soluble carbolic acid and cresol preparations, with chloro-naphtholeum, and with phinotas oil, and in his report for 1907 he gives the results of certain experiments with a substance known as "killarvæ." It is not necessary, however, to consider any of these substances in this connection except to state that phinotas oil has met with considerable use, since it forms a milky compound with water which settles through a pool and destroys not only mosquito larvæ, but all other animal life in the pool. It is used in cesspools and receptacles of that kind, and is also found to be of service in the anti-mosquito work on the Isthmus of Panama.

In another section we have spoken of the use of certain aquatic plants as forming so dense a covering over the surface of the water as to exclude mosquito larvæ from access to air, thus bringing about their destruction. Another method which brings about the same results, although in a different way, is described by Consul Wm. H. Bishop, of Palermo, Sicily, in the Monthly Consular and Trade Reports, No. 331, April, 1908, in which he quotes from an account of the experiments made by the chief of the sanitary service at Gaboon, French Africa, with cactus as a substitute for petroleum in the extermination of mosquitoes in warm climates. Beyond this account by Mr. Bishop we have no further information of this remedy:

> The thick, pulpy leaves of the cactus, cut up in pieces, are thrown into water and macerated until a sticky paste is formed. This paste is spread upon the surface of stagnant water, and forms an isolating layer which prevents the larvæ of the mosquitoes from coming to the top to breathe and destroys them through asphyxiation. It is true that petroleum can do the same service, but in warm climates petroleum evaporates too quickly and is thus of little avail. The mucilaginous cactus paste, on the contrary, can hold its place indefinitely, lasting weeks, months, or even an entire year; and the period of the development of the larvæ being but about a fortnight it has the most thorough effect.

After all we are practically reduced to the use of oils in this kind of work. Some effort has been made to find if there are any other oils that could be used to better advantage than petroleum. A suggestion was once made by Mr. W. J. Matheson that corn oil might be used. This is a substance which is made rather extensively in certain parts of the country and which, considering the enormous crops of corn grown in Western States, which in fact are so great that in past years of overproduction corn has been burned as fuel, might reasonably

[a] Report of the New Jersey State Agricultural Experiment Station upon the Mosquitoes Occurring within the State, their Habits, Life History, etc. Trenton, N. J., 1904.

be supposed to be a cheap oil. This, however, is not the case, and its price is prohibitive as compared with ordinary grades of kerosene. Experiments undertaken in 1900 indicated that corn oil does not spread readily. It gathers together in large patches on the surface of the water, and mosquito larvæ rising to the surface and finding themselves under a patch of oil will simply wriggle violently until they find the spaces between the patches where they breathe comfortably and live for several days. In this experiment the object was not only to secure a cheap and efficient oil, but to secure a persistent oil which will not evaporate and which will remain for at least several weeks over the surface of the water. Its nonspreading qualities, however, as well as its price remove it from practical consideration.

To sum up the whole question of larvicides, nothing has been found more satisfactory as regards efficiency and price than common kerosene of low grade, or better still, that grade known as fuel oil. This conclusion has not only been arrived at in the United States, but elsewhere, although petroleum has been more extensively used in the United States than elsewhere, and it is better understood in this country. In choosing the grade of the oil, two factors are to be considered. First, it should spread rapidly; second, it should not evaporate too rapidly. The heavier grades of oil will not spread readily over the surface of the water, but will cling together in spots and the coating will be unnecessarily thick, as in the case of the corn oil just mentioned. The rapidity of spread of film is also important. Ronald Ross, in his "Mosquito Brigades," pages 34 to 35, makes the following statement:

> Mr. Hankins of Agra informs me that the addition of amyl alcohol greatly expedites the formation of the film; and it is very necessary to obtain a film which makes its way between the stalks and leaves of water weeds.

Early in the course of antimosquito work in the United States careful experiments were made by Mr. W. C. Kerr, in the work of the Richmond County Club, on Staten Island, to which we have referred before. He tried several grades of oil and found a low grade of oil known as "fuel oil" to be best adapted to the work. Of the oils which he tried, some contained too much residuum of a thick nature, which appeared as a precipitate and could scarcely be pumped; some were too thick in July weather and could not be pumped at all, while some were limpid, easily handled, made a good uniform coating on the ponds, and were very effective. So long as oil flows readily and is cheap enough the end is gained, provided it is not too light, and does not evaporate too rapidly. The grade known as light fuel oil was recommended by the writer to the United States army workers in Cuba at the close of the Spanish war and was found to be effective. The price of oil of this kind has varied from \$2.25 per barrel to \$3 per barrel, f. o. b. Philadelphia.

In his early Catskill Mountains experiments the writer ascertained that about an ounce of kerosene to 15 square feet of surface space is about the right proportion, and that such a film would remain persistent for ten days, or slightly longer. He noticed further that even after the iridescent scum had apparently disappeared there was still an odor of kerosene about the water and that adult mosquitoes avoided it.

In the work done by Mr. H. J. Quayle, near San Francisco[a] more or less oiling was done upon ponds that could not be drained, and upon standing pools remaining in creek beds during the summer; and some was also done on marsh lands. The oil used was a combination of heavy oil of 18° gravity, and light oil of 34° gravity in the proportion of 4 to 1, respectively. This mixture made an oil that was just thin enough to spray well from an ordinary spray nozzle, and yet was thick enough to withstand very rapid evaporation. It was applied by means of a barrel pump where this could be used, but in the creeks and other situations, which could not be reached by horse and wagon, the ordinary knapsack pump was used. The price of the heavy oil at Burlingame, Cal., was 2 cents a gallon, and of the lighter oil 2½ cents a gallon. The former was obtained from the Bakersfield district, while the latter was a product of the Coalinga fields. Mr. Quayle found that the duration of efficiency depended somewhat on the nature of the pool and its exposure to the winds, but in no case could it be counted upon as thoroughly effective after a period of four weeks.

This period of four weeks brings up the question as to the frequency of application of kerosene. The persistence of the oil will undoubtedly vary with the temperature and with the character of the pool—whether exposed to the direct rays of the sun or shaded by trees, or exposed to the wind. Three weeks will probably be a good interval with light fuel oil. The army of occupation in Cuba used its oil every two weeks.

The application of kerosene to the surface of the water can be made in any one of several different ways. If it is simply poured upon the surface it will spread itself, or will be spread rapidly by light winds. The spraying method, either with the barrel pump, or by knapsack pump, or bucket pumps, has been frequently used. The writer watched the oiling of ponds with a spraying pump in a New Jersey town several years ago. The water treated was all in small woodland ponds, and there was a great waste of kerosene. The spray was diffused and became scattered over the vegetation on the borders of the pond, a large share of it being wasted in this way, while the shore vegetation was killed. On small ponds the oil

[a] Bul. No. 178, Agr. Exp. Sta., Univ. Cal., 1906.

can be sprinkled to advantage out of an ordinary watering pot with a rose nozzle or, for that matter, pouring it out of a dipper or cup will be satisfactory. In larger ponds, pumps with a straight discharge nozzle may be used. A straight stream will sink and then rise and spread until the whole surface of the pond can be covered without waste. The English workers in Africa advise mopping the petroleum upon the surface of the water by means of cloths tied to the end of a long stick and saturated with kerosene. The use of such a mop may be desirable, even where a straight discharge pump has been used, in order to commingle two or more surface sheets of oil. In some of his early work on Staten Island, Doctor Doty, the health officer of New York, used a pump with a submarine discharge, throwing the oil out at the bottom of a pool and allowing it to rise to the surface. It seems that the idea was to destroy the insects feeding at the bottom more quickly, but as most mosquito larvæ rise to the top to breathe about every minute, there is practically nothing to be gained by such a method of distributing kerosene.

The use of larvacides in tropical regions brings in certain new features which complicate the problem of mosquito destruction to a certain extent. Colonel Gorgas and his corps of workers at Panama have been using petroleum very extensively just as they did at Habana. They find, however, that at Panama the rapid growth of vegetation prevents the oil from spreading uniformly and that it can not make a thin uniform film over the surface of water in which vegetation grows. They find also that algæ on the surface of the waters form with the oil a dark scum, which collects at the bottom of shallow pools. This scum later breaks up and floats about on the surface, rendering succeeding oilings less efficacious and necessitating the use of larger quantities of oil. They also find that where vegetable débris collects in a large body of water it will be blown about as a mass, its location changing with the wind, and thus break the film of oil. Mosquito larvæ also hide in this vegetation, which protects them from fish. The wind blows the oil to one side of the surface and it evaporates very rapidly in the Tropics. During the rainy season it is washed away very rapidly before it destroys all of the larvæ and of course where the film is not perfect the larvæ find free places to breathe. The bulk of the oil and the cost of transportation in rough territory for work on a large scale are disadvantages. In their work they find that they must constantly occupy themselves in removing vegetation before oil is applied, in order to prevent the necessity of using excessive amounts of oil. They find that new growths of algæ appear to develop very rapidly after the oil has united with the previous crop and sunk to the bottom.

In the course of the Panama work, as previously stated, phinotas oil has been used, and has been found to have the following advan-

tages over crude oil: It acts as a poison and kills the larvæ very rapidly. It brings the larvæ out of their hiding places at once and is useful as an aid to the detection of the presence of mosquito larvæ. It is found also that in continuous heavy rains the larvæ are killed by the phinotas oil before the rain dilutes the treated water to any great extent. They find, however, that phinotas oil has certain disadvantages: It kills fish in a solution of 1 to 5,000, and it loses its efficiency very soon after application, so that eggs are laid upon the treated water quickly and the larvæ develop. Doctor Gorgas points out that there is considerable variation in the quality of this substance as shipped to the Isthmus. Some barrels will kill larvæ quickly in a solution of 1 to 3,000 parts of water, while other lots require for the same results 1 part to 1,000. Doctor Gorgas has recently published a list of the desiderata for the perfect larvacide for use in the Tropics, agreeing with the opinion expressed by Ronald Ross when he returned from his first visit to Africa that nothing as yet known is perfectly satisfactory:

(a) Low ultimate cost.

(b) Ability to affect and kill mosquito larvæ promptly, the more rapidly the better. It must be effective in moving water as well as in still water.

(c) Ability to form a solution with water and to thoroughly diffuse and mix with all the water of a small pond if applied only to one part thereof. Also the substance must not lose its larvicidal properties for a week or more after its application. The longer it will retain its larvicidal properties after it has been placed in the body of water the more valuable it will be.

(d) Ability to diffuse in water and through all parts of a body of water such as in a pond containing grass, water lilies, other aquatic vegetation, and vegetable débris.

(e) Ability to kill green algæ promptly.

(f) A concentrated larvicide is necessary so that one part of it to five thousand or more parts of water will promptly kill mosquito larvæ and pupæ.

(g) Nonpoisonous to human life or animals when taken in a strength of 1 to 1,000 and accidentally used as drinking water.

(h) That it have the property of discoloring the water to which it is applied, or of giving off sufficient odor to induce persons not to use water containing it in solution for drinking purposes.

(i) That the odor, if present, be not so obnoxious as to make its presence in water in ponds or streams near habitations undesirable.

(j) That it shall have a safe flash test and be nonexplosive.

(k) That it shall be sufficiently stable so that it may be kept "standardized."

Decoctions and emulsions of *Derris uliginosa* have been recommended for larvicidal use, but experiments conducted at the Wellcome Research Laboratories at Khartoum show that while it has considerable potency it also kills fish, and that even in regions where these plants are native the different species of Derris have only a limited use as insecticides.

During the 1905 outbreak of yellow fever in New Orleans an attempt was made to destroy mosquito larvæ in the open gutters of the city by the use of common salt. Dr. H. A. Veazie wrote us that

the results were good where the work was properly done. Shortly after operations were begun there was a flight into the city of *Aëdes sollicitans* from the salt marshes northeast of New Orleans. Indignant citizens, ascertaining from experts the name and habits of the species, jumped to the conclusion that salting the ditches had brought about suitable breeding conditions for *sollicitans* and that the invasion of the city by that species was a direct result of the work of the sanitary officials. Charging mosquito pools with electricity does not seem to have been tried. Mr. Aaron Aaronsohn, director of the Jewish agricultural experiment station at Haifa, Palestine, tells the writer that Professor Blasius, of Berlin, reading a newspaper account that some electrical workers engaged in the vicinity of a river used the electrical current to catch fish, began, some little time ago, to study the effect of electricity on fish, and that he found that by discharging a current into the water he could stun the fish, but did not kill them. Mr. Aaronsohn suggests that this plan may perhaps be tried to advantage in certain favorably situated localities to ascertain whether it can be practically used against mosquito larvæ.

In the course of the experimental work with larvicides carried on at the Isthmus of Panama Colonel Gorgas and his assistants have constructed a larvicide plant at Ancon, and in the August, 1909, Report of the Department of Sanitation of the Isthmian Canal Commission it is stated that 14,600 gallons of larvicide were made at a cost of $0.1416 per gallon. The following is quoted from this report:

The method of making same is as follows: 150 gallons of carbolic acid is heated in a tank to a temperature of 212° F.; then 150 pounds of powdered or finely broken resin is poured in. The mixture is kept at a temperature of 212° F., 30 pounds of caustic soda is then added and solution kept at 212° F. until a perfectly dark emulsion, without sediment, is obtained. The mixture is thoroughly stirred from the time the resin is used until the end.

The resultant emulsion makes a very good disinfectant or larvacide. In fact, 1 part of it to 10,000 parts of water will kill Anopheles larvæ in less than half an hour, and 1 part to 5,000 parts of water will kill Anopheles larvæ in from five to ten minutes or less. This property of killing larvæ rapidly is of great importance in the Tropics, where continuous rainy periods make crude oil or kerosene much less valuable as a larvicide than it is in northern latitudes having less rainfall. Also, the larvicide acts as an algicide, and thus destroys the food and the hiding places of Anopheles larvæ. As it takes up very little room, compared with the area it can be spread over, the cost of distribution will be much less than that of crude oil or kerosene. Considering the large territory which the antimalarial work covers, this item alone is of great financial advantage to the department.

Tests have recently been made to determine approximately how much of the new larvicide will be needed per month (rainy season) for each district.

Although this larvicide will be used to a large extent, yet we shall continue to use crude oil for streams having a fair velocity, as such application gives excellent results and is as economical as larvicide would be, as the oil is spread in a very fine film automatically. In order to make the crude oil drip with continuous regularity, a piece of metal similar to that part of a flat-wick lamp which holds the flat wick is fastened to the oil container. It is made somewhat larger than the wick, so that the

wick fits it loosely when saturated with the grade of fuel oil we use. This metal wick chamber is fitted to the oil container about 3 inches from its base. The space below the wick chamber is filled with a solution of caustic soda or of larvicide. As the oil is attracted along the wick by capillary attraction, it comes into contact with the larvicide or caustic soda and is "cut"—rendered thinner. This method of procedure prevents the wick from being clogged by the thick fuel oil and enables the wick to drip the oil desired.

In the September, 1909, report it is stated that the new larvicide was giving very satisfactory results and would undoubtedly reduce the cost of antimalarial work, besides being more effective than crude oil in many places. It seems to have some value as a destroyer of vegetation. In the October report satisfaction with its use is again expressed, and it is stated that the fact that it kills the grass at the edges of the ditches will be of importance in reducing the cost of antimalarial work.

ORGANIZATION FOR COMMUNITY WORK.

While in a large measure it is true that every individual householder practically rears upon his own premises the majority of the mosquitoes that bother him, still in a closely built city those reared by one's neighbors must be taken into consideration. In isolated country houses the character of the adjacent region must be considered by the individual who concerns himself with this work, but even here some sort of an organization is desirable, and even frequently necessary, as in cases where swamp lands are to be drained or where occasional invasions of such a migratory species as *Aëdes sollicitans* are to be feared. The control of all sources of mosquito supply in case of fresh water or brackish swamp land is usually too great a task for the individual, although on the large estates of great proprietors such work has been done at individual expense. In any sort of community, however, organization is necessary, not only to carry out the actual work, but to produce and to emphasize a universal sentiment in favor of the mosquito crusade—a sentiment so strong and so general that every individual will cheerfully take part in the work. The pioneers in this country who, in 1901 and 1902, attempted to arouse such a public sentiment had much difficulty in educating the people and in securing funds, but lately it has been an easier matter. Many communities, large and small, have taken up antimosquito measures, and such large cities as New York, Baltimore, New Orleans, and Nashville have given the question serious consideration in their city councils and in their boards of health, and have entered upon measures of greater or less efficacy. Many smaller towns have begun the crusade also, and those which have been especially active have been communities of summer resort. One of the early attempts was the formation of the North Shore Improvement Association of Long Island, which undertook a mosquito campaign

involving over 25 square miles of territory along the north shore of Long Island, the territory including several villages and many country homes of wealthy people. Following the first year's work of this association a national antimosquito society was formed to encourage just this kind of work, and this society has published instructions and pamphlets of information which are at the disposal of all communities desiring to enter upon the task of freeing themselves from mosquitoes.

Work of this kind carried on in Cuba, in Panama, and in various English colonies will be referred to in later sections. All have been well organized and actively carried forward and have been successful in reducing the number of mosquitoes and in correspondingly reducing such diseases as are carried by mosquitoes.

Theoretically, community work should be done under official auspices, and should be inaugurated by boards of health, but official action is slow, even in the United States, where there is, as a rule, less red tape than in older countries. Moreover, official action in sanitary measures is often conservative, as well as slow. As already pointed out, the health question is not the only one involved. Abundance of mosquitoes means enormous economic loss to a community, entirely aside from the important question of health, and individual property owners realize this more than do official bodies. It is only necessary to cite the increased value of real estate at summer resorts where the mosquito scourge has been wiped out, and the great value of reclaimed marsh land for manufacturing sites in the immediate vicinity of great cities, or for agricultural purposes at a greater distance from the great centers of population. An unusual reason for anti-mosquito work developed a few years ago. A famous sportsman, who was at the same time a captain of industry and had also been a cabinet officer at Washington, spent large sums of money in the vicinity of Sheepshead Bay, Long Island, to reduce the abundance of mosquitoes, because his blooded race horses were losing condition from their bites, although he had previously paid no attention to the mosquito problem from the standpoint of human health and convenience or from the standpoint of the value of the real estate in that vicinity, of which he was a large holder.

In community work, therefore, as well as in most other measures of reform, the organization of private citizens has usually been the initial step. Many communities have their own village or town improvement associations, and many cities have their citizens' associations constantly alert to discover needed reforms and improvements and to bring them emphatically to the notice of their elected representatives on the city council and to the mayor's appointees on the board of health. It is through the mosquito committees of such associations that very much of the work in this direction has

been agitated and inaugurated, and doubtless this method will continue most effectively for some time to come.

The first step in undertaking such work is to interest several responsible persons whose names carry weight in the community, and then to raise a small fund, either by appropriations from funds at the disposal of the improvement society, or whatever it may be, or by private subscription. Then these persons, forming a committee, should issue a circular to every householder, signed by the whole committee, reciting very briefly the well-known facts concerning the breeding places of mosquitoes and the measures which should at once be taken by householders. A good plan also would be to have a public lecture given by some expert, well illustrated, to which all householders should be invited. An excellent circular of the character just described was issued in the early summer of 1901 as follows:

THE VILLAGE IMPROVEMENT SOCIETY OF SOUTH ORANGE.

SOUTH ORANGE, N. J.

MAY 27, 1901.

The breeding place of the mosquitoes that may infest your house may be looked for within your own house or grounds, or in your immediate neighborhood.

The mosquito lays its eggs *only upon standing water* and passes the first ten days of its existence in the water.

Without standing water there can be no mosquitoes.

Dr. Howard says: "I feel sure that the cesspools in South Orange must be responsible for a great deal of your mosquito supply." Therefore:

Look to your cesspools, cisterns, water tanks, and any barrels or other receptacles in which water may stand for a few days, either inside or outside the house.

It is suggested that you at once do away with every unnecessary water receptacle.

Put kerosene oil in your cesspools and on surface of necessary standing water once in three weeks.

Oil placed on surface should not affect the taste of water drawn from beneath the surface, but when that is not considered advisable water receptacles should be screened with a fine mesh screen.

The mosquito being not only a serious annoyance, but a constant menace to health, its extermination becomes a matter of public concern.

The cooperation of every household is requested.

Please report to .... the location of any pools of stagnant water in your neighborhood.

After the issuing of the circular or the holding of the public lecture, or both, if the members of the committee are too busy, as they are likely to be, to engage to any extent in the actual superintending work, an intelligent superintendent must be chosen who will familiarize himself with the biology of mosquitoes and especially with the character of mosquito breeding places in general. He should at once be put to work upon a survey of the mosquito topography of the neighborhood. It will be well for him to make a map upon which every breeding place, aside from the chance receptacles about

houses, should be noted with the greatest accuracy and care. Every house having an uncovered water-tank or having rain-water barrels should also be noted, and for each locality the most effective as well as the most economical remedy should be recorded. If these remedies demand any large-scale work estimates of the necessary expenditures should be indicated.

Such a careful report and map having been prepared and placed in the hands of the committee the amount of funds necessary can readily be estimated, and the expenditure of such sums as it is found possible to raise can be considered and agreed upon. The work can then be easily carried on through the summer under the direction of this superintendent, and of course the amount of the expenditure and the number of employes will depend entirely upon the local mosquito-breeding possibilities.

Some small communities will find that a full understanding of the problem on the part of individual householders will bring about great relief as the result of individual work, and that the only organization necessary will be perhaps the signing of a pledge by individuals to take care of their own premises. In other communities the matter will be a little more serious, but there will be some where the employment of a single man for two or three days a week throughout the summer will result in freedom from mosquitoes. Again, however, in larger communities the enforcement of municipal regulations will be found to be necessary before a desirable result can be obtained, and where the village is built upon swampy land or is surrounded by swamps the expenditure of considerable sums of money will be found to be imperative.

In every community, however, there will pretty surely be ultra-conservative, recalcitrant, and ignorant citizens—people who will not take the trouble to prevent the breeding of mosquitoes on their own premises—people in fact who will violently object to the entrance on their premises of an individual who will do the work for them. Such cases are not numerous, but they are always difficult to handle, and, in the absence of municipal action, moral suasion must be tried in the most ingenious ways which the committee can devise. Dr. Ronald Ross, in his excellent work "Mosquito Brigades," in writing of such persons, puts it very happily in the following words:

The qualities chiefly necessary [in a superintendent] are energy, persistence, and an entire indifference to public or private opinion. The need of the first two is obvious; that of the last requires some explanation. The self-appointed superintendent will be at once astonished, and perhaps alarmed, at finding that his philanthropic and wholly harmless efforts are met at the outset by a storm of letters to the local press, demonstrating the absurdity and even immorality of his intentions; proving that mosquitoes cannot be destroyed, that they spring from grass and trees; that they can be destroyed, but that it is wicked to make the attempt because they were created to punish man; that they do not carry malaria, because malaria is a gas which

rushes out of holes in the ground, and rises as a blue mist over the country; they do not carry yellow fever, which is due to the effect of the tropical sun on rotting vegetation; that they do carry malaria and yellow fever, but in such small quantities that they act beneficially as unpaid vaccinators of these diseases; and so on.[a] It is possible to ignore all such epistles, because where they do not contradict each other, some one else is sure to contradict them; but an occasional letter in reply does good, and, to speak practically but rather cynically, serves to stimulate the necessary public interest in the work by keeping the letter-writers at such a pitch of exasperation that they give the campaign a constant stream of gratuitous advertisement in the newspapers. We are permitted to be cynical in a good cause.

Fortunately, operations against mosquitoes can be conducted on a large scale without much reference to private opinion—fortunately, because the inertia of the masses regarding new pathological discoveries is so great that were we to depend upon converting them, nothing would be done for half a century. For some inscrutable reason the man in the street, though he would scarcely think of contradicting a lawyer or an engineer on matters of law or engineering, finds himself quite equal to exposing the absurdities of the whole medical faculty on a medical matter.

These operations require no sacrifices or cooperation on the part of the general public. Most householders are glad enough to have their mosquito larvæ destroyed, and their backyards cleaned up for nothing. The reader, therefore, if he sees fit to start the work we are considering, may quietly proceed in it undisturbed by criticism, and may calculate upon receiving not only as much public support as his work will require during its progress, but the thanks of his fellows at its termination. Indeed, the majority of the public will not be slow to recognize the value of his efforts, even if they do not understand the scientific reasons which have induced him to make them.

In community work, after making an effort to insure the absence of household breeding, the attention of the superintendent should be devoted to chance pools along the public roadway and to breeding places in unused land. Drainage or filling are the best measures to adopt. The superintendent will find it advisable to attempt first to extirpate those breeding places from which the greatest numbers of mosquitoes are issuing. In this way he will the sooner bring about an appreciable diminution of the number of the insects, and of course the sooner this diminution is noticed by the citizens the sooner will popular sentiment unanimously support the work. The less populous breeding places may await treatment until a later date.

Large-scale operations requiring a considerable expenditure of money must be organized very perfectly as to detail. The first example of this large-scale work done in the United States was carried on in the most intelligent way by the North Shore Improvement Association of Long Island, mentioned above. Here, as an initial step, work was done by the superintendent and engineer, Mr. H. C. Weeks, during the summer of 1901. Mr. Weeks completed the survey of the large territory and estimated the cost of all operations. Another survey was made by two biologists, Prof. C. B. Davenport and Mr. F. E. Lutz, of the Cold Spring Harbor laboratory, then of the Brooklyn Institute of Arts and Sciences. These gentlemen positively

[a] NOTE.—Dr. Ross states that he has seen every one of these statements, and many others equally absurd, made at least half a dozen times in the British press.

identified all breeding places. Still another survey was made by the late Prof. N. S. Shaler, of Harvard University, who advised concerning the best methods of reclaiming the salt marshes included in the territory where the brackish-water mosquito breeds. Upon the basis of these surveys and reports the association began in 1902 its active work of extermination.

The following is Doctor Ross's summary of antimosquito work, and it is so admirable that it is quoted in full:

SUMMARY.

17. Summary of objects:

(1) We do not propose to exterminate mosquitoes in any entire Continent.

We propose only to deal with them in the town in which we live, and in its suburbs.

(2) We do not propose to get rid of *every* mosquito even in this town.

We aim only at reducing the number of the insects as much as possible.

(3) We do not think it possible to drain or otherwise treat every breeding-place in the town.

We aim at dealing with as many as possible.

(4) We can not exclude mosquitoes which may just possibly be blown into the town from miles away.

We content ourselves with preventing the insects breeding in the town itself.

18. Summary of methods:

(1) We start work at once with whatever means we can scrape together.

(2) We operate from a center outward.

(3) We clear houses, back yards, and gardens of all rubbish; empty tubs and cisterns containing larvæ, or destroy the larvæ in them by means of oil.

(4) We show people how to do these things for themselves, and how to protect tubs and cisterns by means of wire gauze.

(5) When we have cleared as many houses as we determine to deal with, we clear them over again and again.

(6) We fill up or drain away all the pools, ditches, old wells, and puddles we can—especially those which contain most larvæ.

(7) Such pools as can not be filled up or drained are deepened and cleared of weeds if they contain larvæ.

(8) Streams and water courses which possess larvæ are "trained."

(9) Where we can do nothing else we destroy the larvæ periodically with oil, or by brushing them out with brooms, or by other means.

(10) We endeavor to interest our neighbors in the work, and to educate the town into maintaining a special gang of men for the purpose of keeping the streets and gardens absolutely free of stagnant, mosquito-bearing water.

19. Motto: Our motto should be one which I think will shortly become the first law of tropical sanitation, namely, "*No Stagnant Water.*"

After concluding an account of his own personal work at Lloyds Neck, Long Island, and of the work done by the North Shore Improvement Association, Mr. W. J. Matheson, speaking before the First Anti-Mosquito Convention in New York, December 16, 1903, concluded that as the result of the work carried on it had been demonstrated that, with the exception of the salt-marsh mosquitoes, the mosquito nuisance can be controlled and abated in almost any locality where intelligent cooperation can be secured and a systematic inspection made of the premises for the purpose of destroying the breeding

places. Extermination, in his opinion, will exterminate just as far as the intelligent landowner is willing to carry it, but that it can not be done once and for all any more than weeding a garden or the cropping of a lawn can be done once and for all. He concludes his paper with the following words:

So far as my experience goes, it has been demonstrated that mosquitoes can be as completely exterminated in any locality as dirt can be swept from a building, or as weeds from a walk, with the possible exception of *Culex sollicitans*, and with the exercise of no more intelligence and much less labor than is required in the performance of many domestic duties. My experience would lead me to conclude that if mosquitoes continue to exist in any locality it is because the people are too indifferent to the nuisance to take the trouble to be rid of it.

THE IMPORTANCE OF INTERESTING CHILDREN.

Under the general head of "Remedies" we have mentioned the efforts made by Professor Hodge, in Worcester, Mass., to interest the school children of the city in the search for mosquito breeding places. This must have been in 1901–2. But the most serious and productive effort seems to have been made at San Antonio, Tex., a year or so later, at the initiative of Dr. J. S. Lankford, of that city.

In November, 1903, there were cases of yellow fever in San Antonio which caused several deaths, and an inexcusable interruption of commerce that cost hundreds of thousands of dollars. In the effort to allay the panic, the existence of yellow fever was denied, not only by persons having business interests in the city, but by many medical men as well. Very many adults not only denied the existence of the fever in the city, but denied the relation between the mosquitoes and the fever. Perhaps the majority of the adults seemed too old to learn; and to the enlightened physicians it appeared that it was impossible to begin education at the wrong end of life.

The chairman of the sanitary committee of the school board (Doctor Lankford) grasped the happy idea that if the children were properly educated, sanitary matters in the future would be much better attended to. He suggested to the board that it would be valuable to educate all of the school children of the city in prophylaxis and make sanitarians out of them all. The school board heartily approved of the proposition, and the campaign was at once begun to educate the children on the subject of *Insects as Disease Carriers*. The best recent medical literature on the subject was procured and furnished to the teachers, and a circular letter was sent to them outlining a proposed course and offering a cash prize for the best model lesson on the subject. Teachers became deeply interested in the subject. A crude aquarium, with eggs and wrigglers, was kept in every schoolroom, where the pupils could watch them develop; and large magnifying glasses were furnished in order that they might study to better advantage. The children were encouraged to make

drawings on the blackboard of mosquitoes in all stages of development; lessons were given and compositions were written on the subject. Competitive examinations were held, and groups of boys and girls were sent out with the teachers on searching expeditions to find the breeding places. Rivalry sprang up between the 10,000 public school children of the city in the matter of finding and reporting to the health office the greatest number of breeding places found and breeding places destroyed. Record was kept on the blackboards in the schools for information as to the progress of the competition and great enthusiasm was stirred up. In addition to these measures, a course of stereopticon lectures was arranged, grouping the pupils in audiences of about 1,000 from the high school down, and, in Doctor Lankford's words—

> It was an inspiring sight to watch these audiences of a thousand children, thoughtful, still as death, and staring with wide-open eyes at the wonders revealed by a microscope. It seemed to me that in bringing this great question of preventive medicine before public school children we had hit upon a power for good that could scarcely be overestimated.

The result of this work, it is pleasing to say, was a decided diminution in the matter of mosquitoes in San Antonio. There was some opposition among the people, but the movement on the whole was very popular. One result of this work was that while there had previously been from 50 to 60 deaths a year from malarial trouble, the mortality was reduced 75 per cent the first year after this work was begun, and in the second year it was entirely eliminated from the mortality records of San Antonio.

In organizing community work against mosquitoes, the school children hereafter must be counted upon as a most important factor. Almost every child is a born naturalist, and interest in such things comes to them more readily than anything else outside of the necessities of life. They are quick-witted, wonderfully quick-sighted, and as finders of breeding places they can not be approached except by adults of the most especial training. One of the first steps that a community should take is, therefore, the encouragement of the interest of the children in the public schools.

RECENT WORK IN GERMANY.

The city of Leipzig quite recently has begun a crusade against malaria under the direction of the city council. The following account of this work was sent in by United States Consul S. P. Warner, and is published in the Daily Consular and Trade Reports for April 20, 1909:

> So many cases of malaria have recently occurred in those sections of Leipzig which are adjacent to any one of the four rivulets which flow through the city that the city council has decided to adopt stringent measures to exterminate the mosquitoes (Anopheles) that spread the disease.

In order that the work of extermination may be thoroughly and systematically carried out, the city council has notified all housekeepers in the infected sections of the city to carefully examine their houses or apartments for mosquitoes and to destroy any that may be found. Every household in the districts concerned has been furnished by the city council with a large circular, which, in addition to information as to the cause and spreading of malaria, contains advice as to the best means of destroying the malaria mosquitoes.

Certain dates have been specified between which the houses are to be searched and the mosquitoes destroyed. At the expiration of the time specified inspectors appointed by the city council will visit each house and apartment and make careful examinations to see that the work of exterminating the mosquitoes has been properly carried out. Those who fail to comply with the regulations promptly and thoroughly will be subject to a fine of about $7.50.

WORK ALONG RIVER FRONTS IN EGYPT.

Communities living along river fronts may have good antimosquito work hampered by the constant reintroduction of a mosquito supply from boats landing at their river fronts. This point has been especially noted in the course of the excellent work done at Khartoum. The following passage is taken from the first report of the Wellcome Laboratories, pages 21–22:

At an early period the steamers were found to be largely infected, especially with the larvæ of *Stegomyia fasciata*, and to a less extent by those of *Culex fatigans*. Anophelines, either as larvæ or imagines, have never been met with; but up-country, as will be noted later, the adults are frequently to be seen on board, and may remain as passengers for a considerable period. At first it was decided to use lime for the steamer bilges, but this was said, erroneously I believe, to act upon iron and to be unsuitable. Consequently crude petroleum was recommended, though not so good nor so easily applied. Along with this the periodical emptying of the bilge and fumigation with the sulphur squibs described by Colonel Giles were advised, the latter to get rid of the adult insects. Unfortunately in the case of the steamers, familiarity had evidently bred contempt, for, at first, despite the cooperation of the director of the steamers and boats department, little energy was displayed by the engineers in charge and the preventive measures were largely ignored, and in some instances even ridiculed. This was the more to be regretted, as there is no doubt that mosquitoes can be banished from all the steamers if a little care and trouble were taken. Mr. Beadnell, of the Geological Survey, carried out these simple methods on the S. S. "Nubia," and practically cleared her of mosquitoes, so that for the first time he was able to sleep below in comfort. A great improvement also resulted in the case of the gunboat "Zafir," in which I went to Dueim and found to be simply swarming with adult Culices and their larvæ, while these measures absolutely prevented any mosquitoes breeding out on board the S. S. "Amka" during a period of nearly two months, the greater part of which was passed in regions swarming with these winged pests. Latterly, I am glad to say, the engineers have been impressed with the necessity of doing all in their power to aid the brigade. This is the more necessary, as it is easy for the steamers to infect the town and thus spoil much of the work done and render it futile. I am certain that this has occurred in many instances * * *.

EXAMPLES OF MOSQUITO EXTERMINATIVE MEASURES IN DIFFERENT PARTS OF THE WORLD AND OF THE SANITARY RESULTS FOLLOWING THEM.

It is proposed in this section to describe briefly some of the most striking examples of successful warfare against mosquitoes that have been carried out since 1900 and to bring them together into one consecutive account, a task that has heretofore not been attempted. Of many of them the details are not well known on account of the inaccessibility of the documents of record.

FEDERATED MALAY STATES.

The work was begun at Klang and Port Swettenham in 1901 and 1902, the object being to abolish malaria, which was disastrous in its prevalence and virulence, by the extermination of mosquitoes by means of extensive drainage and the abolishing of breeding places. The town of Klang is situated on swampy ground lying between the Klang River—from which it takes its name—and a semicircle of low hills. Klang was formerly the terminus of the government railway and the port of the State. The river navigation, however, was difficult, and a new port was selected near the mouth of the river, which was opened in September, 1901, and named Port Swettenham. The anchorage was good, but a half mile of mangrove swamp intervened between the shore and a wide extent of flat peaty land. The mangrove swamp was intersected by a narrow road running up from the coast to Klang, some 5 miles away.

After Port Swettenham was opened malaria increased alarmingly; almost all of the laborers were attacked, and many severe cases occurred on board ships lying alongside the wharves. A commission was formed consisting of physicians and engineers, and antimosquito work of an extremely effective and complete character was carried out. The following condensed account of the operations, and the tables showing striking results in the reduction of malaria, are taken from an article by E. A. O. Travers, state surgeon, Selangor, and Malcolm Watson, district surgeon, Klang, published in the Journal of Tropical Medicine for July 2, 1906:

Port Swettenham.—An area of about 110 acres, formerly low-lying swampy land covered with mangrove trees, has been cleared and carefully drained. In the neighborhood of the railway, government buildings, and town site a considerable area has been filled in and leveled, partly to do away with the breeding grounds of mosquitoes and partly to provide building sites. The whole area not occupied by buildings or roads is now covered by grass.

The total expenditure on works other than the preparation of building sites has been (to the end of 1905) £7,000 [$34,020], and the annual cost of upkeep of drains, etc., is approximately £40 [$194.40] for clearing earth drains, and for town gardeners, £100 [$486].

Klang.—The area affected by the operations is about 332 acres. Twenty-five acres of virgin jungle and 80 acres of dense secondary growth (in places 30 to 40 feet high) have been cleared and 36 acres of permanent swamp have been drained. The areas cleared are now mainly under grass.

The total expenditure to end of 1905 has been £3,100 [$15,066], and the cost of annual upkeep is about £60 [$291.60] for clearing earth drains, and £210 [$1,020.60] for town gardeners.

As will be seen from the following statistics of cases of malaria treated at the district hospital, Klang, the improvement in the health of the inhabitants of the areas treated began immediately after the completion of the drainage and other works and has continued to date.

Table showing the number of cases of malaria admitted to the Klang hospital from Klang town and Port Swettenham, as compared to the number of cases admitted from other parts of the district.

Residence.	1901.	1902.	1903.	1904.	1905.
Klang	334	129	48	28	12
Klang and Port Swettenham [a]	88	....	....	....	....
Port Swettenham	188	70	21	4	11
Other parts of district	197	204	150	266	353
Total	807	....	219	298	376

[a] Certain persons lived some nights in Klang and some in Port Swettenham.

The following table shows the number of deaths from fever and other diseases which have occurred at Klang and Port Swettenham during the last six years. The population in 1901 was about 4,000, but has largely increased since.

Deaths in Klang and Port Swettenham corrected for deaths in hospital.

Year.	1900.	1901.	1902.	1903.	1904.	1905.
Fever	259	368	59	46	48	45
Other diseases	215	214	85	69	74	68
Total	474	582	144	115	122	113

It will be noted that the remarkable improvement in the health of the inhabitants which occurred in 1902, immediately after the antimalarial works had been completed, has been well maintained.

The following table shows the number of deaths occurring in the district of Klang, excluding the town of Klang and Port Swettenham. (Population 14,000 in 1901, since largely increased.)

Deaths in Klang district, excluding Klang town and Port Swettenham.

Year.	1900.	1901.	1902.	1903.	1904.	1905.
Fever	173	266	227	230	286	351
Other diseases	133	150	176	198	204	271
Total	306	416	403	428	490	622

These figures are especially valuable as a proof that the marked improvement in the health of the inhabitants of the towns of Klang and Port Swettenham is due to the antimalarial measures carried out, and not to a general improvement in the health of the district.

In Klang and Port Swettenham we have 368 deaths due to fever in 1901, and 45 only in 1905; whereas in the rest of the district, which has not been dealt with by any special antimalarial works, we have 266 deaths due to fever in 1901 and 351 in 1905.

It may here be mentioned that Klang is a large planting district about 380 square miles in extent, that it is mainly low-lying flat land, utilized for the cultivation of rubber, and that it would be almost impossible to protect the scattered population from malaria by drainage and filling in swamps. A great deal is now being done on most of the estates by regular administration of quinine, and also by protection from mosquitoes.

Malaria in children as evidenced by examination of blood.—No better indication of the presence or absence of malaria in any given district can be obtained than by a systematic examination of the blood of children.

The following details of the results of examinations carried out by Dr. Watson in 1904 and 1905 are of considerable interest:

Results of examination of blood of children in Klang and Port Swettenham (specially drained areas).

	November and December, 1904.			November and December, 1905.		
	Number examined.	Infected.	Percentage infected.	Number examined.	Infected.	Percentage infected.
Klang	173	1	0.57	119	1	0.84
Port Swettenham	87	1	1.14	76	1	.00
Total	260	2	.76	195	2	.51

Results of blood examinations in other parts of district not especially drained.

November and December, 1904.			November and December, 1905.		
Number examined.	Infected.	Percentage infected.	Number examined.	Infected.	Percentage infected.
298	101	33.89	247	59	23.8

Improvement in health of government employees.—The remarkable way in which the health of the government employees residing at Klang and Port Swettenham has been affected is well shown by the following figures. It may be mentioned that in 1901 the number of persons residing at Port Swettenham, employed by the Government, was 176, and in 1904, 281.

Table showing number of sick certificates and number of days' leave granted on account of malaria.

	1901.	1902.	1903.	1904.	1905.
Certificates	236	40	23	14	4
Days of leave	1,026	198	73	71	30

The conclusions to be arrived at from the figures given in this report are very evident:

(1) Measures taken systematically to destroy the breeding places of mosquitoes in the towns, the inhabitants of which suffered terribly from malaria, were followed almost immediately by a general improvement in health and decrease in death rate.

(2) That this was due directly to the works carried out, and not to a general dying out of malaria in the district, is clearly shown by figures pointing out that while malaria has practically ceased to exist in the areas treated, it has actually increased to a considerable extent in other parts of the district where antimalarial measures have not been undertaken.

The fact that the statistics for 1905 are even more favorable than those for 1902 is very strong evidence in favor of the permanent nature of the improvement carried out.

If, as it is hoped, malaria has been permanently stamped out from Klang and Port Swettenham by works undertaken in 1901, our experience in the Malay States should be of value to those responsible for the health of communities similarly situated in many other parts of the world.

THE WORK IN HABANA DURING THE AMERICAN OCCUPATION, 1901–2.

One of the most striking examples of clean, efficient antimosquito work is that done by the American troops in Habana at the close of the Spanish war, under the direction of the Army Medical Corps and under the especial direction of Col. W. C. Gorgas, U. S. Army. In the statements which follow, Colonel Gorgas's published writings have been freely used.

Yellow fever had been endemic in Habana for more than 150 years, and Habana was the source of infection for the rest of Cuba. Other towns in Cuba could have rid themselves of the disease if they had not been constantly reinfected from Habana. By ordinary sanitary measures of cleanliness, improved drainage, and similar means, the death rate of the city was improved from 1898 to 1902 from 100 per thousand to 22 per thousand, but these measures had no effect upon yellow fever, this disease increasing as the nonimmune population increased, and in 1900 in fact there was a severe epidemic.

Aëdes calopus was established as the carrier of the fever early in 1901, and then antimosquito measures were immediately begun. Against adult mosquitos no general measures were attempted, although screening and fumigation were carried out in quarters occupied by yellow fever patients or that had been occupied by yellow fever patients. It was found that *calopus* bred principally in the rain-water collections in the city itself; that *Culex quinquefasciatus* bred everywhere, and that *Anopheles argyritarsis* bred principally in the suburbs in pools and puddles well protected with grass. Two mosquito brigades were started—one to take care of *calopus* and the other *Anopheles*.

The work of the so-called "Stegomyia brigade" was confined to the built-up portions of the city. The city was divided into about thirty districts, and to each district an inspector and two laborers were assigned, each district containing about a thousand houses. The mayor of Habana issued an order requiring all collections of water to be so covered that mosquitoes could not have access, a fine being imposed in cases where the order was not obeyed. The water supplied Habana was very hard, and it was customary for every

family to collect rain water in barrels. As the majority of the people in the large tenement houses were poor, and as each family had a rain barrel, the health department covered these barrels at public expense, leaving a small screen opening through which the water could run and placing a spigot at the bottom through which it could be drawn. Every house in Habana, on the average, has a cesspool, the liquid contents generally seeping into the soil. The inspector on each visit had from 4 to 6 ounces of petroleum poured into the cesspool, and where this was not accessible it was poured into all closets connected with the cesspool; all receptacles containing fresh water that did not comply with the law were emptied, and, on a second offense, destroyed. If the owner was an old offender, he was prosecuted under the law and fined.

As a result of this work of the so-called "Stegomyia brigade," whereas in January, 1901, there were 26,000 fresh-water receptacles containing mosquito larvæ, in January, 1902, there were less than 400 such receptacles containing larvæ; mosquitoes had rapidly decreased, and were entirely absent in many parts of the city. The result of this work, thoroughly done, was to wipe out yellow fever in Habana, and there has not been a certain endemic case since.

The "Anopheles brigade" was organized for work along the small streams, irrigated gardens, and similar places in the suburbs, and numbered from 50 to 300 men. No extensive drainage, such as would require engineering skill, was attempted, and the natural streams and gutters were simply cleared of obstructions and grass, while superficial ditches were made through the irrigated meadows. Among the suburban truck gardens Anopheles bred everywhere in the little puddles of water, cow tracks, horse tracks, and similar depressions in grassy ground. Little or no oil was used by the Anopheles brigade, since it was found in practice a simple matter to drain these places. At the end of the year it was very difficult to find water containing mosquito larvæ anywhere in the suburbs, and the effect upon the malarial statistics was striking. In 1900, the year before the beginning of the mosquito work, there were 325 deaths from malaria; in 1901, the first year of mosquito work, 151 deaths; in 1902, the second year of mosquito work, 77 deaths. Since 1902 there has been a gradual, though slower decrease, as follows: 1903, 51; 1904, 44; 1905, 32; 1906, 26; 1907, 23.

WORK AT THE ISTHMUS OF PANAMA.

The United States Government has very properly used the services of Colonel Gorgas, who was in charge of the eminently successful work at Habana, by appointing him chief sanitary officer of the Canal Zone during the digging of the canal. In 1904 active work was begun, and Colonel Gorgas was fortunate in having the services

of Mr. Le Prince, who had been chief of his "mosquito brigades" in Habana, and therefore was perfectly familiar with antimosquito methods. In Panama, as in Habana, the population had depended principally upon rain water for domestic purposes, so that every house had cisterns, water barrels, and such receptacles for catching and storing rain water. The city was divided up into small districts with an inspector in charge of each district. This inspector was required to cover his territory at least twice a week and to make a report upon each building with regard to its condition as to breeding places of mosquitoes. All the cisterns, water barrels, and other water receptacles in Panama were covered as in Habana, and in the water barrels spigots were inserted so that the covers would not have to be taken off. Upon first inspection, in March, 4,000 breeding places were reported. At the end of October less than 400 containing larvæ were recorded. This gives one a fair idea of the consequent rapid decrease in the number of mosquitoes in the city. These operations were directed primarily against the yellow-fever mosquito, and incidentally against the other common species that inhabit rain-water barrels. Against the Anopheles in the suburbs the same kind of work was done which was done in Habana, with exceptionally good results.

The same operations were carried on in the villages between Panama and Colon. There are some twenty of these villages, running from 500 to 3,000 inhabitants each. Not a single instance of failure has occurred in the disinfection of these small towns, and the result of the whole work has been the apparent elimination of yellow fever and the very great reduction of malarial fever. The remarkable character of these results can only be judged accurately by comparative methods. It is well known that during the French occupation there was an enormous mortality among the European employees, and this was a vital factor in the failure of the work. Exact losses can not be estimated, since the work was done under 17 different contractors. These contractors were charged $1 a day for every sick man to be taken care of in the hospital of the company. Therefore it often happened that when a man became sick his employer discharged him, so that he would not have to bear the expense of hospital charges. There was no police patrol of the territory, and many of these men died along the line. Colonel Gorgas has stated that the English consul, who was at the Isthmus during the period of the French construction, is inclined to think that more deaths of employees occurred out of the hospital than in it. A great many were found to have died along the roadside while endeavoring to find their way to the city of Panama. The old superintendent of the French hospital states that one day 3 of the medical staff died from yellow fever, and

in the same month 9 of the medical staff. Thirty-six Roman Catholic sisters were brought over as female nurses, and 24 died of yellow fever. On one vessel 18 young French engineers came over, and in a month after their arrival all but one died. Now that the mosquito relation is well understood, it was found during the first two years under Doctor Gorgas that although there were constantly one or more yellow-fever cases in the hospital, and although the nurses and doctors were all nonimmune, not a single case of yellow fever was contracted in that way. The nurses never seemed to consider that they were running any risk in attending yellow-fever cases night and day in screened wards, and the wives and families of officers connected with the hospital lived about the grounds, knowing that yellow fever was constantly being brought into the grounds and treated in near-by buildings. Americans, sick from any cause, had no fear of being treated in the bed immediately adjoining that of a yellow-fever patient. Colonel Gorgas and Doctor Carter lived in the old ward used by the French for their officers, and Colonel Gorgas thinks it safe to say that more men had died from yellow fever in that building than in any other building of the same capacity at present standing. He and Doctor Carter had their wives and children with them, which would formerly have been considered the height of recklessness; but they looked upon themselves, under the now recognized precautions, as safe almost as they would have been in Philadelphia.

No figures of actual cost of the antimosquito work either in Habana or in the Panama Canal Zone are accessible to the writer, but it is safe to say that it was not exorbitant and that it was not beyond the means of any well-to-do community in tropical regions.

WORK IN RIO DE JANEIRO.

One of the most difficult problems of this character was that of freeing Rio de Janeiro from its reputation as the great yellow fever center. The difficulties were very great, and the amount of money required for efficient work was enormous. Rio de Janeiro has a population of more than 800,000 people; it extends over an area of 430 square miles; it is very irregular in its topography, varying in altitude from 1 to 460 meters (3 feet to 1,509 feet) above the sea level; it has 82,396 houses, and, as in all great centers of population, the inhabitants of very many of the houses, if not resisting the efforts of the sanitary authorities, surely did not facilitate them. The effort was begun in April, 1903, under the direction of the public-health service, but the organization effected was of a temporary character and needed the passage of new laws by congress, which was effected in January, 1904, and resulted in the reorganization

of the hygienic service of Brazil and created a service for the stamping out of yellow fever. One million six hundred and fifty thousand dollars was appropriated annually for this work. The service established included 1 medical inspector, 10 sanitary inspectors (physicians), 1 administrator, 1 customs inspector, 1 accountant, 70 medical students, 9 subchiefs, 200 overseers, 18 guards of the first class, 18 guards of the second class, and 1,000 workmen; and in addition to this personnel, the assistance of the public-health service corps of inspectors was called upon. The city was divided into zones, according to the density of the population, and the work was divided into two sections: (1) Isolation and sanitation; (2) the policing of the infected districts. Under the first section, yellow-fever patients were removed to the pesthouse, residents were isolated, and houses were disinfected. Under the second, the sanitary police force visited every building in the city, destroyed the early stages of mosquitoes, and screened standing water where possible. One force worked in buildings, and another in vacant lots, streams, marshy lands, etc. The following paragraphs relative to this work are quoted from an address made before the Latin-American Medical and Sanitary Congress, held in Rio de Janeiro August 1 to 10, 1909, by Dr. Oswaldo Cruz:

Yellow-fever cases were made known to the sanitary inspectors by the reports of medical assistants, of the head of the family in which a case occurred, or by any one to whom the facts of the case were known, in accordance with the requirements of the law. The sanitary service being advised, a competent group of inspectors and authorities were at once dispatched to the locality, having with them a physician. The latter ascertained if the case was one for isolation treatment (whether under or over four days after the onset of the disease), and if the case required isolation the same was carried out either in the dwelling house or in the hospital, hospital treatment being resorted to only when the dwelling was unsuited to isolation treatment or when the patient wished it. In such cases the patient was taken to hospital in a vehicle closed against the entrance of mosquitoes, and the house was disinfected in accordance with the system below outlined. In the case of isolation in the home the physician chose a roomy quarter of the house with door opening into another secluded part of the house and with windows. If there were more than one door, the others were temporarily closed. The patient was kept under a netting enveloping the bed upon which he lay during the time permanent quarters were being arranged. The doors and windows of the room to be isolated and of the rest of the house as well were sealed to prevent the exit of mosquitoes existing there, the windows of the isolated room being fitted with wire screens in such a way as not to interfere with ventilation, all other openings to the outside or to other parts of the house being sealed with cloth or paper. The only door to be used in the use of the room must be specially fitted with a double door drum, provided with an arrangement which does not permit of both doors being opened at the same time. This apparatus prevents the entrance and exit of mosquitoes, and after the room is thus prepared the door and windows are closed and camomile is burned in the room 3 to 4 hours in the proportion of 10 grams per cubic meter of space. The room is then well ventilated and is ready to receive the patient. The rest of the house is well calked and isolated from the room in which the patient is placed, and disinfected with sulphur gas, as below indicated. During this operation a sanitary inspector remains in the room

with the patient and stops the entrance of any gas which may possibly find its way through some overlooked crevice. During the preparation for disinfection the sanitary authorities make a thorough inspection and destroy any mosquito larva they find, pick up or destroy any vessels lying about which might serve as a receptacle for mosquito-breeding water, and close water boxes against the same danger. The patient remains in isolation for seven days, after which isolation may terminate, if the family so wishes. The infected district is then treated as above indicated; that is, by disinfection, sanitary policing, and medical supervision. Disinfection is carried on in two ways, one force working from the center toward the outer limits of the district and the other from the boundaries of the district inward. The area of infection being determined over as large an area as possible, these two sections separate, one of which begins immediately with the house in which the case of yellow fever occurred, the other beginning at those houses which might possibly have been infected at the greatest possible distance from the case in isolation. The purpose of such a system was to destroy all mosquitoes which might have carried infection within the district.

While the disinfecting force is thus at work the police division, under the direction of a physician and of students who direct the different sections, operates throughout the infected district, making every effort to destroy all mosquito larvæ and to prevent the possible breeding of mosquitoes outside as well as inside the house. Where larvæ are likely to exist in stagnant water or refuse of any sort, petroleum mixed with creoline, lysol, or similar products is thrown over the water or refuse in sufficient quantity to kill the larvæ instantly. Where it is impossible to use petroleum, as in the case of tanks and boxes for household use, a small fish, the "barrigudo" or *Girardinus caudimaculatus*, is placed in large numbers in the water. This fish destroys the larvæ of mosquitoes most voraciously. Larvæ in the drains are destroyed by the use of "Clayton gas," which is pumped into the sewer, which has been previously divided into compartments. Simultaneously with the disinfection the sanitary inspectors make daily inspection of the suspected district, examining every inhabitant supposed not to be immune—that is, children under 5, and all foreigners of less than 5 years' residence in Rio. These are subjected to the closest vigilance, being placed in isolation at the least tendency to rising temperature. Reports are made in writing, those to whom this duty falls being required to fill out daily a bulletin sent out by the medical inspector to the chief of each district. In this report must be given the record of any who work outside the district or who for any reason absent themselves therefrom, a record of their condition being also kept by the physician in the district in which they work or are temporarily resident. When any inhabitant absents himself from the district the record must show his address, where he will be subjected to vigilance on the part of the authorities there. If the person under vigilance evades the attention of the physician and withdraws without giving notice, the owner of the house in which he lived is fined, he himself is apprehended by the sanitary police, fined, and subjected to renewed vigilance.

The vigilance in each district extends over a period of one month after the appearance of the last case. To give an idea of this service we will note the figures covering the prophylactic campaign in the infected district about the cotton factory, "Fabrica das Chitas," in 1906. The inspection was carried out by 18 doctors, who examined daily all suspected persons—in all, 7,966 persons, of whom 2,989 were not immune. Sixty cases were reported, of which only 19 proved to be yellow fever, and the district was declared entirely freed of infection after six months. With the combination of the three systems there is no doubt about cleaning up effectively any district in which yellow fever may appear. In normal conditions the police service is carried out with equal painstaking, especially in the districts where infection last appeared. When, after some time, there seems no longer to be danger of new infection, the inspectors allow water to stand in several marked spots most favorable to mosquito breeding.

These pools are then carefully watched, and examined at frequent intervals. This is a sure way to indicate the presence of the mosquito, and is a trap for those about to spawn. They are thus most easily destroyed. In many zones of the city these traps revealed the presence of no mosquitoes whatever.

The actual results which followed this admirable work are shown by a table indicating the death rate from yellow fever in Rio from 1872 to date, which indicates that perfect success has been reached.

Mortality from yellow fever in Rio de Janeiro from 1872 to August, 1909.

Year.	Deaths.	Year.	Deaths.
1872	102	1891	4,456
1873	3,659	1892	4,312
1874	829	1893	825
1875	1,292	1894	4,852
1876	3,476	1895	818
1877	282	1896	2,929
1878	1,176	1897	159
1879	974	1898	1,078
1880	1,625	1899	731
1881	257	1900	344
1882	89	1901	2,299
1883	1,608	1902	984
1884	863	1903	584
1885	445	1904	48
1886	1,449	1905	289
1887	137	1906	42
1888	747	1907	39
1889	2,156	1908	4
1890	719	1909	0

WORK IN ALGERIA.

In 1902 an antimalarial campaign was begun in Algeria under the auspices and at the expense of the Pasteur Institute of Paris. The work was begun in a small way, and the service was afterwards extended and supported by the Algerian government and is still being carried on. Dr. Edmond Sergent was assigned to the work, and in 1903 published an account of the early demonstrations. The investigators propounded to themselves the following question: Is it possible, under the practical conditions existing in Algeria, to defend a group of Europeans from malaria? And they decided to use no prophylactic measures whatever except the destruction of Anopheles. The management of the East Algerian Railroad placed at the disposal of the service one of the stations of that line. This station, which was called Alma, was a hotbed of malaria. Nine agents had been stationed there between the 1st of July, 1894, and the 1st of December, 1901. All of them were seriously ill with malaria, and the first eight left their positions on account of malarial fever on the advice of their physicians. The ninth was the man in charge at the time, who was very thoroughly infected. The families of these agents, concerning which there were no statistics, were all and always feverish, according to the best information. It seems that there did not exist a person who had ever lived in this station a single summer without contracting malaria.

At the time when the work began, June 26, 1902, there were 13 people living in the station; among them 9 had been there a year or more and were malarious; 4 had arrived during the winter and had never had any fever. In the neighborhood of the station there were two families, one of Arabs and one of French. All members of these two families were malarious and refused to be protected, and therefore constituted a constant source of infection for the Anopheles. It was the same way with the travelers who came to the station to wait for trains leaving in the evening or at night. Most of them were Arabs coming from near-by places notoriously unhealthy. The conditions of the problem were then severe. It was necessary to protect from the bite of infected Anopheles 4 persons not previously exposed and 9 others already malarious, the latter from reinfection. The measures undertaken were to protect this group of people from adult Anopheles and to destroy the Anopheles larvæ. This was done in the usual way. The openings to the buildings were screened—doors, windows, and chimney. All breeding places were searched for and found and were treated with kerosene. On leaving the station at night veils and gloves were used; but in spite of this watchfulness it was not certain that all of the house people invariably observed this precaution. The results were excellent. The numbers of the mosquitoes were greatly reduced by the work against the early stages; the building was almost entirely protected, so much so that but 9 Anopheles succeeded in gaining entrance. At the end of the season not one of the 4 new people had shown the slightest symptoms of malaria, a condition which it is safe to say had not occurred before in that locality, and the others, although having some fever, showed no indication of reinfection.

This was only an initial experiment to prove what could be done, and the results were placed before the governor-general of Algeria and the members of congress as well as the departmental and communal authorities. The expenses incurred amounted to $58.83. The governmental efforts since that time seem to have been very considerable. In 1904 malaria was pandemic in Algeria, but by increased knowledge and increased efforts the report for 1908 shows that in that year the situation was very much better and not to be compared with that of 1904. The effort takes the form of conducting demonstrations in order to give lessons to the people and to widen each year the territory covered, and to organize antimalarial campaigns in different malarial localities by the physicians, the engineers, etc., stationed in those localities. Propagandic work of all kinds is going on, including placards in the railway carriages and elsewhere and teaching antimalarial measures in all the schools. The last report published—that giving an account of the operations for 1908—indicates an awakening of the country that can not fail to be productive of great good.

WORK IN ISMAILIA.

Another striking example of excellent work of this kind is found in the report, published in 1906, on the suppression of malaria in Ismailia, issued under the auspices of the Compagnie Universelle du Canal Maritime de Suez. Ismailia is now a town of 8,000 inhabitants. It was founded by De Lesseps in April, 1862, on the borders of Lake Timsah, which the Suez Canal crosses at mid-distance between the Red Sea and the Mediterranean. Malarial fever made its appearance in very severe form in September, 1877, although the city had up to that time been very healthy, and increased so that since 1886 almost all of the inhabitants have suffered from the fever. In 1901 an attempt to control the disease was made on the mosquito basis, and this attempt rapidly and completely succeeded, and after two years of work all traces of malaria disappeared from the city. The work was directed not only against Anopheles mosquitoes, but against other culicids, and comprised the drainage of a large swamp and the other usual measures. The initial expense amounted to $9,650 and the annual expenses since have amounted to about $3,531.90.

The results may be summarized about as follows: Since the beginning of 1903 the ordinary mosquitoes have disappeared from Ismailia. Since the autumn of 1903 not a single larva of Anopheles has been found in the protected zone, which extends to the west for a distance of 3,281 feet from the first houses in the Arabian quarter and to the east for a distance of 5,906 feet from the first houses in the European quarter. After 1902 malarial fever obviously began to decrease, and since 1903 not a single new case of malaria has been found in Ismailia.

WORK IN VERACRUZ.

The president of the superior board of health of the Republic of Mexico, Dr. Eduardo Liceaga, was one of the first to grasp the importance of the mosquito discoveries of the American army board and one of the first to make an effort to put them into effect. As elsewhere, he met with conservatism and a certain amount of disbelief, but it was not long before he succeeded in establishing an antimosquito service for practically all of the towns in which the disease appeared to be endemic, and devoted especial attention to the larger seaports most frequently entered by foreign vessels. In 1893 the disease spread in an epidemic form to several cities of the Gulf States of Mexico and to some interior cities as well, such as in the States of Nuevo Leon and San Luis Potosi. By the aid of strong executive orders on the part of President Diaz, the superior board of health was able to take action in all of the States except one, and was able to arrest the epidemic. The plan of campaign was based upon the mosquito doctrine, and the measures involved the isolation of patients, the rigorous disinfection of dwellings by sulphur dioxid, the drainage

of swamps, covering of drinking-water reservoirs, and the use of petroleum.

In the course of this work and that which followed, with the understanding that Veracruz is the oldest and most permanent focus of endemia of the Mexican Republic, and that all the epidemics had found their origin in that place, the principal attention of the superior board of health was devoted to that city. The town was divided into four districts, each of which was placed under the charge of an experienced physician, and each of these had first-class sanitary agents. Subordinate to these, other second-class agents were appointed, and a certain number of laborers were added. As a result of this effective organization, Carroll, writing his chapter on yellow fever for Osler's Modern Medicine, at the close of 1906, was able to make the following statement:

> In Mexico yellow fever has been eradicated from its endemic focus at Veracruz through the able efforts of Eduardo Liceaga, the president of the superior board of health, whose complete grasp of the problem and whose enlightened and energetic action has added support to the mosquito doctrine, and would have controlled the disease absolutely if the same means of enforcement were available in Mexico as in Cuba in 1901.

The later developments of the work in the Mexican Republic under Doctor Liceaga's leadership have been remarkable. In the American Journal of Public Hygiene, new series, Volume VI, No. 1 (February, 1910), is published Doctor Liceaga's Annual Report on Yellow Fever in the Mexican Republic, from August 16, 1908, to date, a paper read before the American Public Health Association, at Richmond, Va., October, 1909. The following paragraphs concluding this report will give an idea of the excellent results which have followed the work of the sanitary officials in Mexico:

> The campaign against yellow fever, which commenced in the Mexican Republic in the year 1903, has continued uninterrupted up to this date, without even suspending it during the winter months as is done in other countries; that the war on the mosquitoes is so efficacious that there are none left in Veracruz, and, consequently, there are no stegomyias, as demonstrated by the reports rendered by the physician of the Public Health and Marine-Hospital Service of the United States, who is resident in that port.
>
> The cases which have been observed in Merida and surrounding villages arise from the existence in that city of over thirty thousand water tanks which could not be so easily and securely watched as those of Veracruz.
>
> In the entire section which was formerly devastated by yellow fever we continue to canalize the deposits of standing water and to fill up the hollows, as well as to spread oil on all those ponds which cannot be otherwise filled in or covered.
>
> We continue to fumigate the dwelling houses, workshops, schools, etc., in which we have encountered either cases of yellow fever or any suspected cases.
>
> We continue the surveillance over the passengers who travel by rail in any part of the region which formerly suffered from yellow fever, and this service is especially active along the line of the Tehuantepec Railroad.
>
> In the ports of Coatzacoalcos, on the Gulf coast, and Salina Cruz, on the Pacific, it is nearly four years since a single case of yellow fever was observed.

WORK IN JAPAN.

Work in Japan as early as 1901, under Surgeon Major Tsuzuki, confirmed experimentally the malarial relations of Anopheles, and later a large-scale experiment was carried on among the Japanese troops occupying Formosa, which, on account of its extent, served to set at rest any doubts which had previously existed as to the value of mosquito protection. Portions of Formosa are malarious, and the following table indicates the conditions existing among these troops from 1897 to 1900:

	Number of patients.	Number of deaths.	Ratio of patients.	Ratio of deaths.
			Per cent.	*Per cent.*
1897	41,825	267	272.435	1.739
1898	34,752	270	249.394	1.938
1899	29,371	284	221.263	2.139
1900	30,224	272	222.414	2.002

On the 21st of September, 1901, and extending through to the 28th of February, 1902, work was carried on by order of the governor of Formosa, on the advice of Doctor Koike, surgeon-general, as follows. This account of the experiment is taken from an address by Dr. K. Tamura, delegate from Japan to the Eleventh Annual Meeting of the Military Surgeons of the United States Army, June 7, 1902:

Half of the second company, first battalion of infantry at Kirun, Formosa, 115 in number, was employed from the day of their landing at Kirun, and we gave it the name of "protected troops." This troop was thoroughly provided with means of protection from mosquito bites. They were confined in the casern from half an hour before sunset to half an hour after sunrise, the casern having been specially made to prevent mosquitoes entering, and they wore gloves and coverings of the head specially made for that purpose when on service at night.

The results of these new methods for the prevention of malaria were absolutely good. Another half of the second company (called by us "comparison troop") and all the other companies of the battalion (called by us "unprotected troop") had a great many malaria patients, but the protected troop had none.

The table of the number of patients is as follows:

	Average number of men.	Number of patients.	Ratio of patients.
			Per cent.
Protected troop	114.49	0	0
Comparison troop	104.34	34	32.59
Unprotected troop	646.36	285	44.09

The experiment of Grassi in Italy shows that 5 cases of malaria were observed among 112 persons, and Celli observed 11 cases in 203 persons, but our case shows none in 114 persons.

The news was spread rapidly in the whole island and all the troops despatched there became very cautious regarding the bites of mosquitoes. This caution itself gave good results, and the number of patients and deaths decreased distinctly last year, compared with the preceding years:

	Number of patients.	Number of deaths.	Ratio of patients.	Ratio of deaths.
			Per cent.	*Per cent.*
From 1897 to 1900, average	34,043	27,325	242.514	1.947
1901	22,438	14,500	173.211	1.119

Now it is very clear that the prevention of malaria is secured by guarding against mosquitoes, and we believe that Formosa will become a healthy island within a few years.

In the recent war between Russia and Japan, the Japanese gave the world an example of field sanitation hitherto unequaled in history, a vivid account of which will be found in "The Real Triumph of Japan," by Dr. Louis Livingston Seaman, formerly surgeon-major, United States Volunteers (New York, 1907), from which the following facts are drawn:

Longmore's tables, based on the records of the battles of the last two hundred years, show that there has rarely been a conflict of any long duration in which there have not been four deaths from disease to one from bullets. In the Spanish-American war there were 14 deaths from disease to 1 from battle. Japan in her war with China in 1894 lost 3 from disease to 1 from bullets; but from February, 1904, to May, 1905, in her war with Russia 4 were lost in battle to 1 only from disease, the exact figures being 52,946 lost in battle and 11,992 lost from disease, and the significant fact must be added that of the total sick only 3.51 per cent were sick with infectious diseases. There were only 1,257 cases of malaria in the whole army, 600,000 strong, in the eighteen months duration of the war, whereas in 1894, in the war with China, there had been 41,734 cases of malaria. At the outset of the campaign the purifying of cities occupied was begun and attention was paid to mosquito breeding-places. One of the orders issued was that the waste water of the barracks should be connected with the town gutters. Incidentally it may be noted that all articles sold publicly were required to be covered to protect them from flies. In the book of health instructions issued to soldiers occurred the paragraph, "Malaria is spread by mosquitoes; therefore protect yourself from them as much as possible." The soldiers had their camp kettles with them, they were furnished with water boilers, and all water had to be boiled before being drunk. They were furnished with mosquito bars, and every man was enveloped in a bar during the mosquito season. The result of 1,257 cases of malaria out of an army 600,000 strong must be contrasted with a telegram sent from General Shafter at Santiago on August 8 during the Spanish-

American war, which read "At least 75 per cent of the command has been down with malarial fever, from which they recover very slowly * * *." It should be noted that Major Seaman was disappointed not to find mosquito nettings in the main hospital in Tokio and that he states that this hospital was inferior in this and certain other respects to the second and third reserve hospitals in Manila. He states that at some of the hospitals netting was added as the mosquito season approched, but it is only fair to infer that at this main hospital the Japanese surgeons knew what they were about and were certain that the absence of the mosquito bars involved no danger to the patients.

ANTIMOSQUITO WORK IN OTHER PARTS OF THE WORLD.

Nothing has been said in this bulletin about the admirable work which had been carried on in Italy. Taking a prominent part in the demonstration of the conveyance of malaria by Anopheles, the Italian investigators were practically the first to begin active antimosquito work. Their results were so striking that they received the attention of the entire civilized world, many accounts having been published in newspapers and magazines and in more permanent form. The whole world may, in fact, be said to be familiar with this work, which will be, however, more extensively mentioned in a bulletin on malaria and the malaria mosquitoes which it is hoped to publish later in the year.

Active and well-organized antimalarial work is being carried on in many places in the Tropics, and an effort has been made to establish an antimalarial league in Greece which has the support of wealthy people and of the nobility of several countries, but in practically none of the well-settled countries in temperate regions has any work of importance been done, even in regions whose development is distinctly held in check by this disease. The government of India has never been able to carry out broad concerted measures of any great importance, although most important investigations have been carried on in that country. It was recently decided to convene a conference to examine the whole question and to draw up a plan of campaign for the consideration of the general government and of the local governments. This conference assembled at Simla on October 11, 1909. In the resolution which brought about the call it is pointed out that the actual death rate from malarial fever in India is 5 per 1,000; that this represents about 1,130,000 deaths, and, as mortality in malarial fever is ordinarily low, a death rate of even 5 per 1,000 indicates an amount of sickness, much of it preventable, which clearly calls for the best efforts that government can make to diminish it. An editorial in the Journal of Tropical Medicine and Hygiene for

September 15, in speaking of this resolution and the proposed conference, anticipated that nothing will come out of the movement. It says:

> To those, however, who have read many similar resolutions and have perhaps acted on committees of the sort, the solemn rigmarole, with its characteristic touch on the "prohibitive costs of attempts to exterminate the mosquito," implies no more than an expedient to stave off the dreaded day when public opinion will force the government of India to act instead of to talk on this really and literally vital question.

The report of the conference as given in Nature, November 5, 1909, indicates that many important addresses were made, including one by Colonel Leslie, the sanitary commissioner of the government of India, and others by such well-known workers as Major James and Captain Christophers, of the Indian medical service. Colonel Leslie advocated quinine prophylaxis. Major James introduced a discussion upon the distribution of malaria in India and advocated a general investigation in every province similar to that which Captain Christophers made in the Punjab. Quite in the line of prophecies of the editorial in the Journal of Tropical Medicine and Hygiene, Major White, of the Indian medical service, stated that he considered the recommendations of past malaria conferences are costly, and almost prohibitively so if undertaken annually, and contended that more should be done with the propagation of fish which prey upon mosquito larvæ. At the termination of the conference various conclusions and recommendations were drawn up under the following main headings: (1) Scientific investigation; (2) the agency by which investigation should be made; (3) practical measures, including (a) extirpation of mosquitoes, (b) quinine treatment and prophylaxis, (c) education, and (d) finance.

In the United States, it is sad to relate, almost nothing has been done in the way of an active campaign against malaria alone, even in restricted localities. It is true that extensive work has been done against mosquitoes, but in the most of these cases the incentive does not seem to have been to better the health of the people or to stamp out malaria. We have shown that in the New Jersey work the item of personal comfort is concerned and that of the enhanced value of real estate and the enhanced taxable value of land to the community, but the main fight there is conducted against mosquitoes that have no relation to disease, although Doctor Smith has written much against malarial mosquitoes and has conducted a strong educational campaign. We have shown also that the fight against mosquitoes in the marshlands back of Brooklyn was financed by a wealthy man whose immediative motive was to keep his race horses in better condition by preventing the annoyance to them of mosquitoes. In different communities there have been intelligent and up-to-date citizens who have made strong efforts to start malarial campaigns, but we have

not reached success, through indifference on the part of city councils or other bodies controlling public funds. Many health officers themselves have seemed indifferent on this subject. In some localities citizens' associations, civic improvement societies, and women's clubs have made efforts to improve the situation. Good work was done by such an orgainzation in South Orange, N. J., and instances of this kind are scattered here and there at very long intervals over the country, but these efforts as a rule were at first spasmodic and only temporary in their effects.

The city of Baltimore offers an excellent example of what we have just stated. It was early shown that a very large part of the mosquito supply could easily be handled, and there were not lacking intelligent and enterprising citizens who, year after year in the public press and before the board of health and the city council, continually agitated the subject of antimosquito work. Finally in 1907 Mr. George Stewart Brown, a member of the city council, succeeded in getting an appropriation to start the work for that year. Much of this money was expended in expensive advertising in the street cars, etc., but the remainder was expended very efficiently, but necessarily with only partial results, by organizing a gang of men to drain and fill up pools in vacant lots around the suburbs. The next year the appropriation was reduced, and only the gang of men was continued. During 1909 no appropriation was made, the gang of men was dropped, and the whole question was abandoned. It should be stated, however, that before the appropriation was made an ordinance was passed by the city council requiring every householder to remove, screen with wire netting, or keep covered with oil, all standing water on his premises, but it seems that no real attempt was ever made to enforce this ordinance. Of course such an attempt could hardly be successful at first without the aid of a special appropriation for the purpose. At the present time the ordinance seems to be a dead letter.

It is true that even where not directed specifically against malaria, but against the mosquito nuisance, the breeding places of Anopheles are disposed of, and they are for the most part prevented from breeding, together with the other species of mosquitoes, and for this reason a little space will be devoted to some of the productive efforts which have been made in the United States aside from those which have already been considered at some length in the section on drainage and other neighboring sections.

In the early days of antimosquito work in this country, 1901 and 1902, the rather rare citizens who appreciated the situation and who did their best to stir up their communities to organized effort should be mentioned, and among them we have specifically in mind Dr. Albert F. Woldert, of Philadelphia and later of Texas; Dr. Henry Skinner, of Philadelphia; Dr. H. A. Veazie and Dr. H. G. Beyer and

a little later Dr. Quitman Kohnke, of New Orleans; Mr. H. C. Weeks, of Bayside, Long Island; Mr. W. J. Matheson, of Lloyds Neck, Long Island; Major Barton, of Winchester, Va.; Dr. W. S. Thayer, of Baltimore; Mr. Wm. Lyman Underwood, of Boston; Dr. A. H. Doty, of New York; Mr. Spencer Miller, of South Orange, N. J.; Dr. W. F. Robinson, of Elizabeth, N. J.; and Dr. J. W. Dupree, of Baton Rouge, La. We have not mentioned any entomologists in this list, but surely Dr. John B. Smith, of New Jersey; Prof. Glenn W. Herrick, of Mississippi; Dr. E. P. Felt, of New York; Prof. H. A. Morgan, of Louisiana; Dr. W. E. Britton, of Connecticut; and Mr. D. L. Van Dine, of Hawaii, should be named, and of course since those early days nearly every economic entomologist has become an apostle. After 1902 the ranks became greatly increased, and at the present time conditions are being bettered, although still without the existence of any large well-organized campaign directed solely against malaria.

One of the best pieces of work with a direct antimalarial bearing that has been carried on in this country, and that was begun at an early date, is that started on Staten Island under Doctor Doty, the health officer of the port of New York. The following account is largely taken, word for word, from a letter recently received from Doctor Doty, but it can not be directly quoted on account of occasional necessary alterations of the verbiage of a personal letter.

Staten Island, lying in New York Harbor, had had a rather unenviable reputation on account of the great number of mosquitoes present and the continued presence of malaria. It was largely on account of the latter condition that Doctor Doty began his investigation in 1901. He soon found that there were two factors to deal with in this work, namely, the inland mosquitoes and the salt-marsh mosquitoes.

In the extermination of the inland mosquitoes, the section of Staten Island which was known to contain many cases of malaria both in the acute and chronic forms was selected for experimental work. This section consisted of a basin or lowland about a mile square, containing about 100 small dwelling houses some distance apart. Within its boundaries were a large number of stagnant pools varying in size from 10 feet in diameter to an acre or more in area. A house-to-house visit showed that at least 20 per cent of the inhabitants of this district were suffering with some form of malaria, and in the immediate vicinity of every house were found typical breeding places in the shape of old tinware, rain-water barrels, cisterns, cesspools, and ground depressions, many of which contained larvæ. For the purpose of detecting the presence of adult Anopheles, glass tubes fitted with cotton plugs were distributed among the occupants of these houses, with the request that the mosquitoes found in the

house at night be captured and placed in the tubes. In the collection were found many Anopheles. These were particularly numerous in tubes coming from a small group of houses. In one of the latter was found a family consisting of five persons, all of whom showed the acute or chronic form of malaria. Doctor Doty himself secured live mosquitoes from the interior of this house. On the first evening 5 were captured, and all but one were Anopheles. On the second evening 22 were collected, and of these more than one-half were Anopheles. In a house on the opposite corner was found a patient suffering from an acute attack.

In the beginning considerable difficulty was found in detecting the breeding places of the Anopheles, but this became easier as the inspections became more thorough. For instance, in a group of two or three houses close together, a number of Anopheles were captured, but their breeding place could not be found for some time. Finally, in the backyard of one of the houses, overgrown with weeds, was discovered a very large metal receptacle filled with Anopheles larvæ and with many adults in the immediate vicinity. This receptacle was almost entirely covered by underbrush.

After this experience the men employed learned to make the closest possible search and to find probably every breeding place.

The island was then divided into small districts, which were visited by a mosquito corps consisting of five men, one of whom was a sanitary police officer connected with the New York City department of health. The equipment of the mosquito corps consisted of a large wagon provided with spades, rakes, hoes, scythes, and petroleum oil. A house-to-house inspection was made in each district. House owners or tenants were required to remove from about the premises all receptacles which might act as breeding places, or to protect them. Rain-water barrels and cisterns were covered with wire netting, all roof gutters were repaired, and pools of water were covered with petroleum. In certain instances orders were sent to the owners of property containing depressions in the soil to fill them or drain them. If these orders could not be enforced, the mosquito corps returned every ten days or two weeks and applied more petroleum. Copies of a circular of information were delivered so far as possible to each house on Staten Island by police officers, and this educational campaign brought about valuable cooperation on the part of the public.

In 1905 the details of this work were presented to the department of health of the city of New York, and the city government granted an appropriation for the drainage of the swamp land along the entire coast of the island. With the aid of this appropriation, ditching was carried on somewhat in the same manner in which it has been carried on in New Jersey. Down to the present time between 800 and 1,000 miles of ditches have been dug. The swarms of mos-

quitoes soon practically disappeared, window screens were discarded, and meals were served upon the verandas of the hotels.

With the malarial and other inland mosquitoes the work was carried on in the manner above described, not only in the built-up portion of the island, but also in the open spaces between the small and scattered settlements. During the past two years cases of malaria on Staten Island have become practically unknown, and for the past year Doctor Doty has been unable to secure any Anopheles, whereas in the beginning of the investigation they were found almost everywhere on the island. The statistics of the department of health indicate the decrease of malaria from 1905 on. Prior to 1905 malaria was not regularly reported, but the number of cases was surely very much greater than that reported in that year. Since 1905, however, they are stated to be as follows: 1905, 33 cases; 1906, 54 cases; 1907, 4 cases; 1908, 6 cases; 1909, 5 cases.

The work of exterminating malarial mosquitoes has been necessarily slow, as the area involved is considerable, the island being about 16 miles long and from 4 to 6 miles wide, probably containing over 80,000 inhabitants, with large areas between the various towns.

The expense of the operations down to the present date has been about $50,000; this of course includes the expense of the extensive drainage operations in the salt marshes. Doctor Doty, in addition to being the health officer of the port of New York, is a commissioner of health of New York City, and he carried out this work in his capacity as a municipal officer and not as a state official.

There were some earlier and very much smaller pieces of work, which have previously been described by the writer.

Dr. W. N. Berkeley, in the Medical Record of January 26, 1901, gave a most interesting account of a malarial outbreak in a small town near New York City during the summer of 1900. Around a large pond in the vicinity of the town four or five fresh cases had recently developed in August. The first case was that of a coachman, who had caught malaria elsewhere and had relapsed. From his quarters in a long row of stables on one side of the pond the infection had passed along to other stablemen and servants on the same side, to the distance of a quarter of a mile from the original site, and a quarter of a mile in another direction across the pond one other case appeared in a small child. Doctor Berkeley went to the town and discovered that *Anopheles quadrimaculatus* was fairly abundant in every bedroom in that area in which proper search was made. The breeding places seemed to be segregated pools at the end of the pond (the pond itself contained fish) and post holes and excavations. These last were numerous, as many buildings were going up. The following practical measures were adopted: (1) Extermination of all the Anopheles found in houses by a party of men

sent out for the purpose, and this was followed by a systematic introduction of screens in windows and doors; (2) filling in of the smaller breeding places and the drainage of the pond; (3) the seclusion of every malarious patient by netting and otherwise from the bite of mosquitoes, so long as he had germs in his capillary blood. The results were as prompt as they were gratifying. Not a single new case of malaria developed; Anopheles disappeared entirely from houses where it had been previously a night terror, and Culex was greatly diminished in numbers.

Another interesting case has been described by Rev. William Brayshaw, of Chaptico, Md. Chaptico is situated at the head of a widespreading bay or elbow of the Wicomico River, about 8 miles from the point where this river enters into the Potomac at Rock Point. The tide is ordinarily about 2 feet at the full. The village rests between two hills of 80 or 90 feet elevation. The valley is almost flat, and consists of marshy pools, in which the mud or ooze can easily be pierced with a strong pole to a depth of several feet. Three of these pools or ponds are directly in the rear of the house known as the rectory, in which he resided with his wife on June 24, 1890. Neither of them had ever had malaria or fever before, but the mosquitoes were so numerous that it was impossible to take rest at night for a while. On July 11 his wife was taken with malaria, and on September 4 had to be removed to the mountains. Mr. Brayshaw himself was sick most of the time, and every house in the village had from one to five persons suffering from malaria. He proposed ditching and drainage, but there was no money, and everybody laughed at the idea, as many of the citizens had lived there from childhood to an advanced age. There did not seem to be sufficient fall to carry off the "effete matter." On May 19, 1900, he gained the consent of the property owners to ditch through their land a distance of 560 feet to Chaptico Creek. He paid for this himself. The expense was about $40. The result he sums up as follows:

During the summer of 1899, from May to October, the mosquitoes were so numerous that life was a burden during the night, and they were so small that nets seemed to have no effect upon them. From May to October, 1900, quite a number visited us, until June 12, when they disappeared, and we were free from them until the last six days in September, when I found a local cause for their breeding. In the summer of 1899 every house in the village had from one to five persons sick with chills and fever and other malarial troubles; doctors in constant attendance. In the summer of 1900 there were only two sporadic cases of chills, both caused by negligence or inattention to ordinary caution. Everyone in the village seems quite free from malaria since July 10.

Later some excellent work was instituted through the combined action of the boards of health of Cambridge and Belmont, Mass., to improve the sanitary condition of the cities of Cambridge, Somer-

ville, and the towns of Arlington and Belmont, at the inspiration of Mr. W. L. Underwood, a member of one of the boards of health. This was effectively carried out at an expense of $600 without assessment upon landholders. An account of this work by Mr. Underwood is given in the Technology Quarterly of March, 1901.

The work of the North Shore Improvement Association of Long Island has been mentioned rather fully in the sections on remedies. This work was thorough and resulted in the improved sanitation of that portion of Long Island. In 1903 some extensive work was done in Newport, R. I., at the expense of the property holders, under the direction of Mr. Henry Clay Weeks, with good results. The Citizens' Association of Flushing, Long Island, later took up the problem, and with the assistance of the board of health extensive drainage operations have been carried on but are not yet completed. At Wellfleet, Mass., other work of a somewhat similar character, but directed for the most part against the salt-marsh mosquitoes, is now under way.

A most interesting bit of work was carried on in the southern part of the Borough of Brooklyn in 1902–3, under the supervision of Mr. Weeks, which has been described in the chapter on remedies. This work, which was of an expensive character, was lately paid for by a private citizen, Mr. Whitney.

An important step forward was taken in 1903 in the formation of the American Mosquito Extermination Society, in which W. J. Matheson, of New York, the president, and Henry Clay Weeks, also of New York, the secretary, were the leading movers. This society, in which nearly all persons actively interested in the mosquito crusade became interested, was started for the purpose of educating the public, bringing about legislation, and securing cooperation and interchange of ideas. It held its first antimosquito convention December 16, 1903, in the rooms of the Board of Trade and Transportation, Mail and Express Building, New York City. The convention was called to order by Mr. Henry Clay Weeks as acting chairman, who made some introductory remarks, after which officers were elected. The following papers were read:

"How a State Appropriation May be Spent," by John B. Smith.

"What a Rural Community Can Do," by Walter C. Kerr.

"The World-Wide Crusade," by L. O. Howard.

"Does Extermination Exterminate Mosquitoes?" by W. J. Matheson.

"Remarks on Extermination Work at Morristown, New Jersey," by John Claflin.

"The Extermination and Exclusion of Mosquitoes from Our Public Institutions," by P. H. Bailhache, surgeon, U. S. Public Health and Marine-Hospital Service.

"Government Antimosquito Work," by Dr. J. C. Perry.

"The Sphere of Health Departments," by Dr. E. J. Lederle.

"The Exactness of Proofs of Transmission of Malaria by Mosquitoes," by Dr. W. N. Berkeley.

"The Long-Distance Theory," by Spencer Miller.

"The Value of Reclaimed Swamp Lands for Agricultural Uses," by Milton Whitney.
"Antimosquito Work in Havana," by Col. W. C. Gorgas, U. S. A.
"How the Law Should Aid," by Paul D. Cravath.
"New York State's Part in Mosquito Extermination," by E. P. Felt.
"What the Government Should Do," by F. C. Beech.
"Mosquito Engineering," by Henry Clay Weeks.
"The Work of the Department of Health, New York City," by Henry C. Weeks.

Following this organization meeting, a somewhat elaborate organization was perfected, including an advisory board and an advisory board of entomologists. The proceedings of the convention were published in pamphlet form and were distributed free of charge. A mosquito brief was published as a folder giving mosquito information. In November, 1904, Bulletin No. 1 of the society was published, which contained in digested form an account of the work which had been going on in the meantime. Bulletin No. 2 contained a report of the president and secretary to the executive council, published September 26, 1905, and in 1906 was also published a yearbook for 1904–1905, which contained the proceedings of the second annual convention of the organization. These proceedings contained a number of valuable addresses, some of which may be mentioned:

"Diversities among New York Mosquitoes," by E. P. Felt.
"Mosquito Extermination in New Jersey," by John B. Smith.
"Extermination and Dissection of Mosquitoes," by M. J. Rosenau of the United States Public Health and Marine-Hospital Service.
"Mosquito Extermination in New York City," by Thomas Darlington.
"The Mosquito Question," by Quitman Kohnke.
"The Relation of Mosquito Extermination to Engineering," by Cornelius C. Vermeule.

The society continued its work, and unquestionably well justified its organization. In 1907, however, it was deemed by the officers of the society that the objects of its existence could well be taken over by the National Drainage Association, which had then recently been formed and which placed among its most prominent motives the idea of securing favorable government action in redeeming the marshes and swamps of the country. It was decided that the society should retire from its field of work and leave the same to the Government, States, and other authorities and to individuals, and the society then disbanded.

In 1903–1904 work against mosquitoes was undertaken by the State entomologist of Connecticut, Dr. W. E. Britton, who made careful mosquito surveys over the whole State and who published in his annual report for 1904 a careful and well-illustrated article devoted to showing how the mosquito nuisance can be abated. Since that time some active work has been taken up. In 1906 the board of health of Millburn Township in New Jersey secured the services of Mr. Weeks, and published a pamphlet entitled "The Mosquito Nuisance in Millburn Township and How to Abate It."

At Worcester, Mass., an interesting crusade was begun early under the direction of Dr. William McKibben and Prof. C. F. Hodge. In Michigan work was carried on upon the campus of the Michigan Agricultural College. In Connecticut work was earlier done at Pine Orchard and Ansonia, as well as at Bridgeport, Branford, Fairfield, and Hartford; and in Maine at Old Orchard Beach. Excellent work was also done at a very early date at Lawrence, Long Island, largely against malarial mosquitoes, under the auspices of the board of health, working with an appropriation of $1,000 and with a privately contributed fund of $1,678.84. A small crusade was also carried on at an early date under the auspices of the civic committees of the Twentieth Century Club at Richmond Hill, Long Island. In the Southern States the boards of health of Atlanta and Savannah began work in 1903 and certain regulations were enforced. At Talladega, Ala., work was also begun in the same year. The excellent work done at Morristown, N. J., under an improvement society in 1903 should not be forgotten.

The work which has been done in Cuba and in the Isthmian Canal Zone has been elsewhere described. In the Territory of Hawaii work was begun in Honolulu in 1903 against the local mosquito plague. It should be stated that Anopheles mosquitoes are not known in Hawaii, and that although the yellow fever mosquito occurs there in numbers the disease has never been introduced. A general campaign, however, was begun under the auspices of the board of health and commercial bodies of Honolulu, and a meeting was held on August 15, at which a citizens' committee of Honolulu was organized to work in cooperation with the board of health and to be supported by subscriptions. The president of the board of health was made chairman of the committee, and a salaried agent was placed in charge of the work. A campaign was continued for a year and a half, at a cost of nearly $3,000, donated entirely by public-spirited citizens. With the help of this fund the citizens' committee demonstrated conclusively that it was possible to rid the city of the mosquito nuisance. Continuation of the work, however, on the basis of private subscriptions, was found impracticable, and later the work was turned over to the board of health and an item of $7,200 to continue the campaign for two years was proposed for the regular appropriation bill of that department of the territorial government at the session of the next legislature. The item, however, did not receive the indorsement of the administration in the interests of economy, and the board of health since that time has relied upon money from private subscriptions and carried on the work as actively as possible with the small amount gathered both in Honolulu and other districts of the island. In the course of this work mosquito-eating fish were introduced, as shown in the chapter on utilization of natural enemies of mosquitoes.

CONCLUSION.

It will thus appear that, considering the economic loss existing in the United States through malaria, nothing like the competent work has been done that should have been done, or really that should have been done in the past eight years within the territorial limits of the United States themselves. The United States Government has done admirable work in Cuba, for another people, and it has done excellent work in the Isthmian Canal Zone, but in its own home territory it has done nothing. State governments have done almost nothing, if we except the drainage work done in New Jersey. Malaria campaigns have been local and on the whole very unsatisfactory.

The writer in 1903, in a paper read before the First Anti-Mosquito Convention in New York, December 16, after summarizing the work which had already been done in different parts of the world, under the title "The World-Wide Crusade," said:

> The main incentive to all this world-wide movement has been the prevention of disease. Probably nowhere else in the world has the motive of personal comfort entered into the crusade as it has in the United States, and we have already carried this aspect of the work much further than any other country. When we consider the enormous sums of money spent in the United States for luxuries, how much more should be spent for bare comfort and peace!
>
> Abundant evidence has been gained in the important work which has been done here and elsewhere during the past two years to show that mosquitoes in any definite region can be reduced to a point far below the danger line and quite within the comfort line, and in many instances it has been shown that they can be exterminated, at least for a time. This work will undoubtedly continue, but there are many communities which need constant prodding. The organization of the antimosquito forces in this convention which you are to hold will greatly stimulate public opinion, and will induce many of the indifferent to take a more sanguine view of possibilities, and perhaps more energetic action toward actual work.

The same comparative indifference holds in other countries, and often even where work is begun under good auspices and with excellent indications it has failed of securing the best results. Maj. C. E. P. Fowler, R. A. M. C., in his report on malarial investigations in Mauritius, 1908, points out that on that island the great fault has been in nonattention to small details, such as the formation of an organization to deal with the neglected surface water found in the small ditches along roadsides, in field drainage channels, and small collections of water in holes in the ground, and to keep up the larger work which has already been carried out. He states that no allowance or forethought seems ever to have been expended on keeping the work already carried through in proper working order. Where drains or ditches had been laid down only a few months previously he found them time after time choked with vegetation and forming excellent places for Anopheles. The same thing was found in the rivers; the government had cleared them, but it seems to have been nobody's

business to keep them clear. According to this report, there seems to be a general impression among all classes of people, not only in Mauritius but elsewhere, that to carry on antimalarial work means the outlay of vast sums. People prefer to sit idle and complain that they have not the means to carry out the work. He shows that a few gangs of men can do a great deal in the way of ridding a district of breeding grounds, and that their employment does not need a heavy outlay.

Looking over the whole field, it is easily seen that work in this direction has hardly begun. There is so much to do in comparison with what has been accomplished or what has really been undertaken that it is almost discouraging when we consider that it is already eleven years since the function of mosquitoes in the carriage of disease was established. It seems as though such a discovery as this should have commanded immediate and widespread attention and should have caused the liberal expenditure of money from many sources in the effort to rid the human race of some of the most serious obstacles to sanitary progress.

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